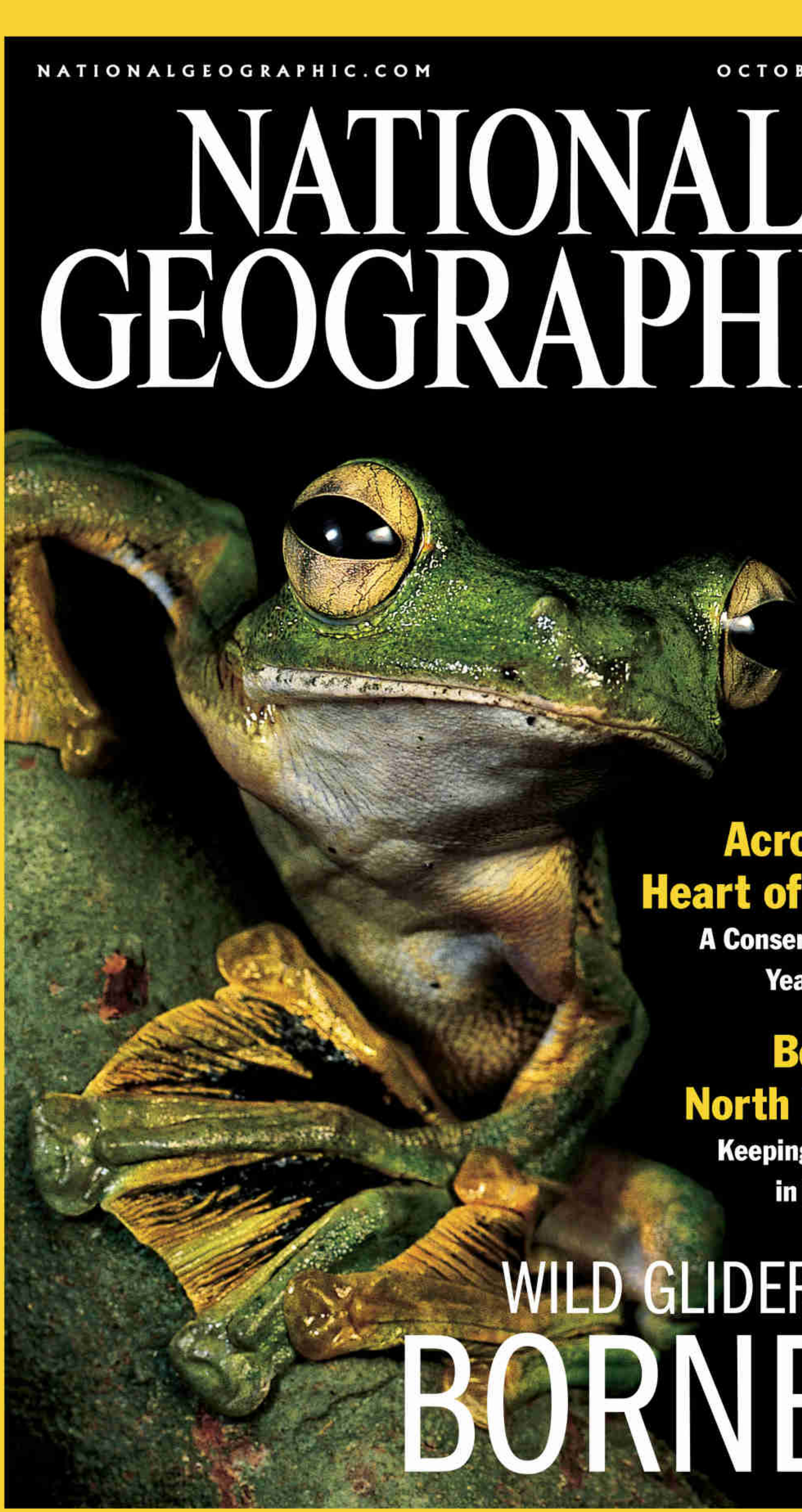
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A Conservationist's Yearlong Trek

Boston's North Enders

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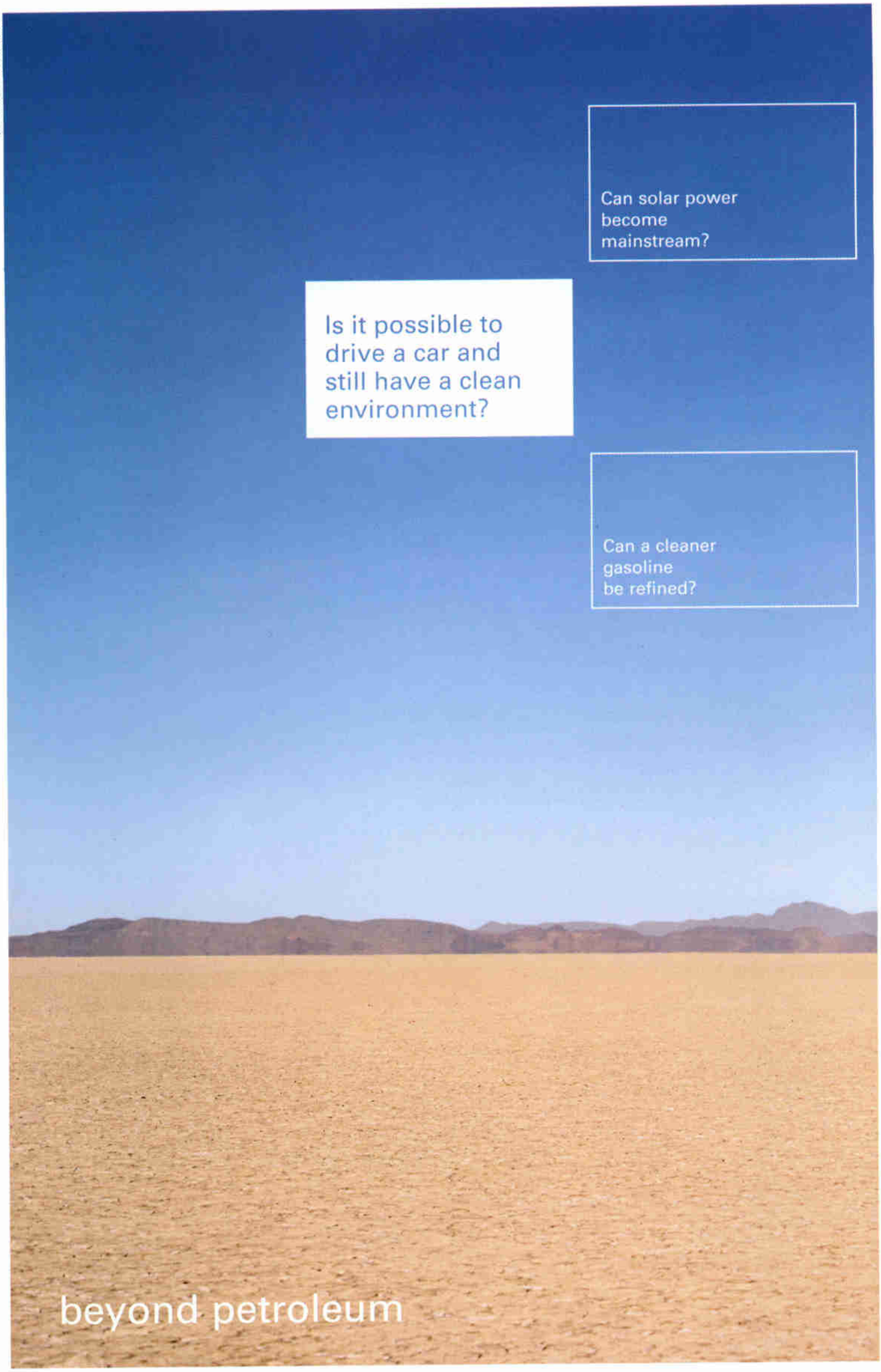
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BY LEWIS M. SIMONS

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THE COVER

After a nighttime descent from Borneo's forest canopy, a Wallace's flying frog clings to a lichen-covered log above a pond where it will breed.
PHOTOGRAPH BY TIM LAMAN

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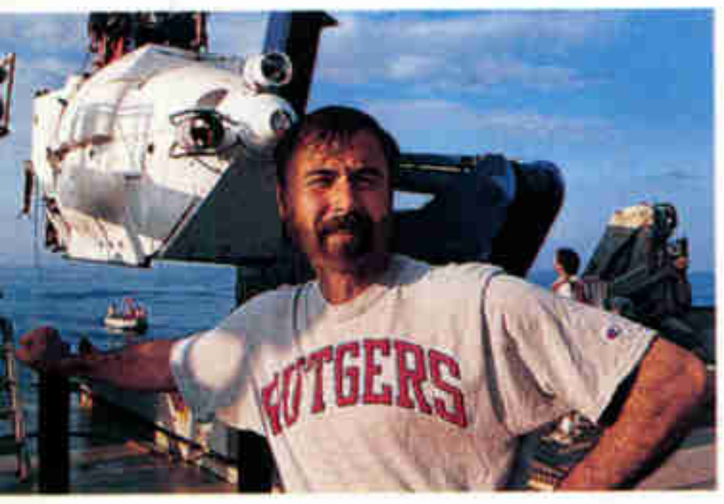
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From the Editor



For the past hundred years or so the deep ocean has been NATIONAL GEOGRAPHIC's beat—from an 1899 report on the "Deep-Sea Exploring Expedition of the Steamer 'Albatross'," by Hugh M. Smith, to the pioneering Society-sponsored work of William Beebe, Jacques-Yves Cousteau, and Robert Ballard. This month we begin a new century of deep exploration, bringing you unprecedented images of the strange creatures that cluster around impossibly hot vents in the ocean floor. Those images are the result of dedicated collaboration among institutions and scientists like biologist and author Rich Lutz (left) and filmmakers and photographers like longtime contributor Emory Kristof (bottom). Unsung heroes in these dives are the pilots and technicians who tend the nonhuman stars of the show—submersibles such as the Woods Hole Oceanographic Institution's *Alvin* and the Russian *Mir* (top, being recovered in 40-knot winds) that carry scientists 20,000 feet below the ocean's surface.



Why pursue such dangerous and expensive missions to belching fissures at the bottom of the sea? Let me leave you with this thought: It is entirely possible that life on our planet was born right there.

Bill Allen



MICHAEL V. DeGRUY (ABOVE); EMORY KRISTOF

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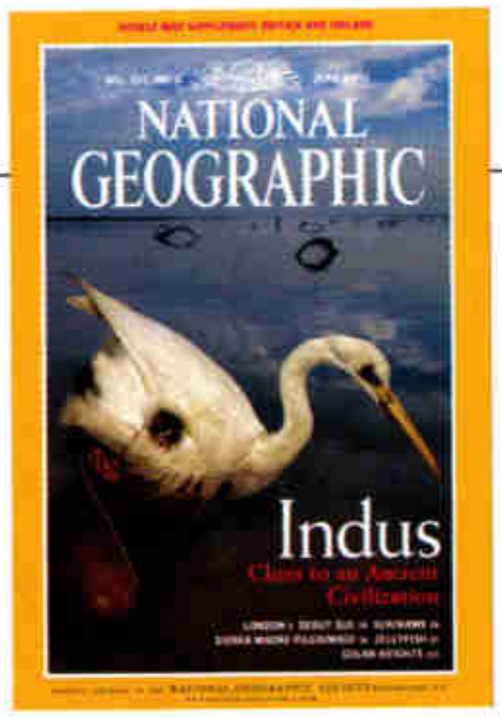
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Forum

June 2000

Readers of the June issue were enchanted by Paul Salopek's pilgrimage through the Sierra Madre in Mexico. One said, "As a sometime writer, I am rotten with jealousy." Another wrote, "I know now why he received the Pulitzer Prize."



London

I found the observation that London is "the de facto capital of Europe" interesting. In many respects it seems like the American capital on the other side of the Atlantic. While the Eurostar may be "packed with French," the busiest international air route in the world is London–New York.

JIM STEFAN
Nanuet, New York

London is a thriving city for some lucky people, but that is only half the story. When cruising with Norman Foster's helicopter, the author should have taken a short detour to the darker sides of London. According to UNICEF the United Kingdom has one of the worst records on childhood poverty in the industrialized world. Every fifth child in the U.K. lives in poverty.

JAN TENHAVEN
London, England

Britain and Ireland Map

On the northwest coast of France only two of the five D day invasion beaches are named: Utah and Omaha, where U.S. forces landed. What about Juno, Gold, and Sword beaches, where Canadian, British, French, and other liberating forces also fought and died?

C. JOHN PARKER
Etobicoke, Ontario

Your map highlighted the little-known fact that there is more than one language spoken in Britain today. Welsh, or Cymraeg, was first spoken some 1,500 years ago, making it one of the oldest languages in Europe.

GETHIN RHYS
Ammanford, Wales

The map states that at Culloden the English defeated the Scottish rebels in 1746. It was the British Army, led by the brutal Duke of Cumberland, the son of King George II from Hanover, Germany, that defeated the Jacobite rebels led by Prince Charles Edward Stuart.

RONALD A. GRANT
Derby, England

Suriname

In 1994-95 I had the opportunity to live and work in Suriname through a cultural exchange program sponsored by the Canadian International Development Agency. Your article captured the diversity of this intriguing country both in text and image.

RUTHANNE HENRY
Phoenix, Arizona

I was taken aback by the assertion that Surinamers turn their eyes to Amsterdam when they think of the outside world.

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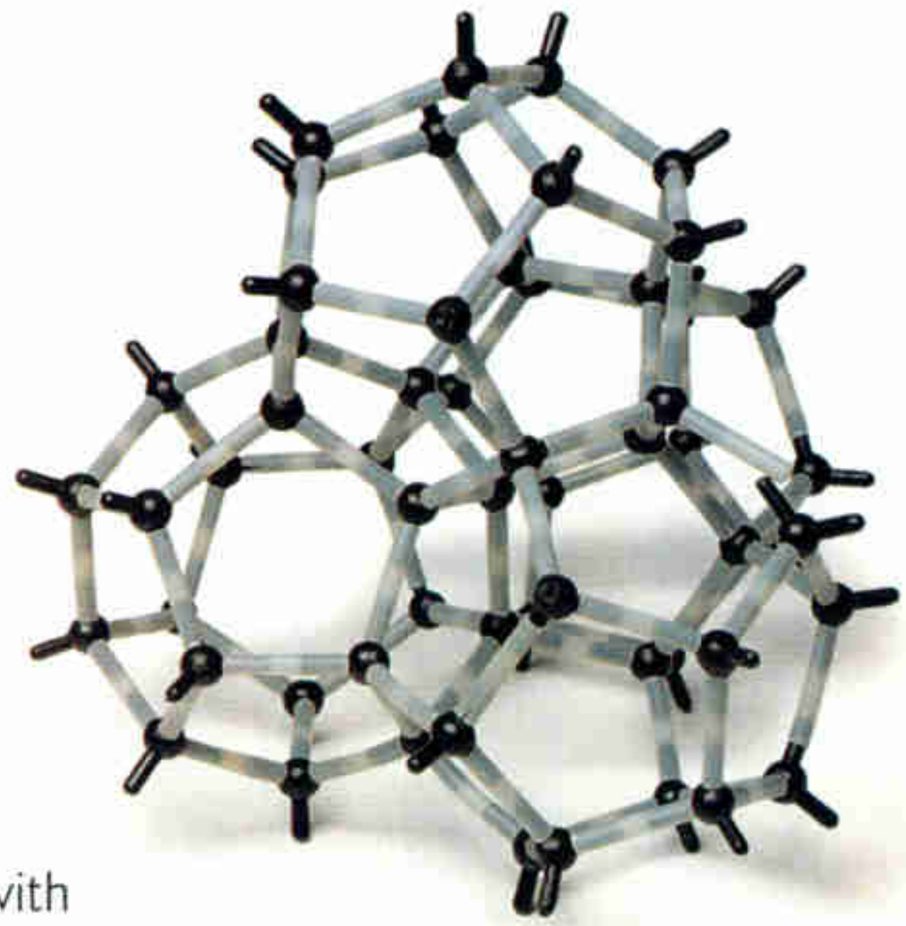
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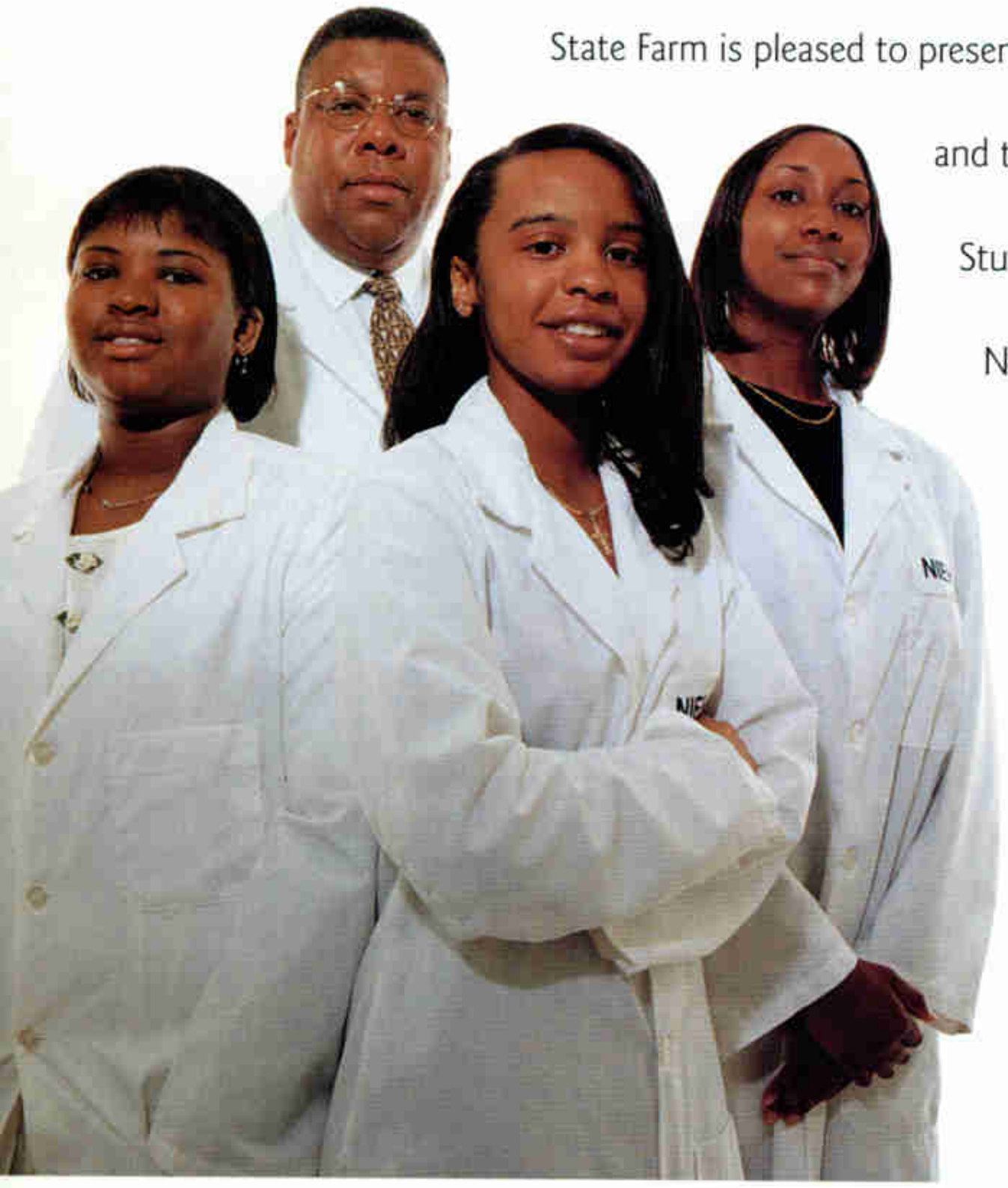
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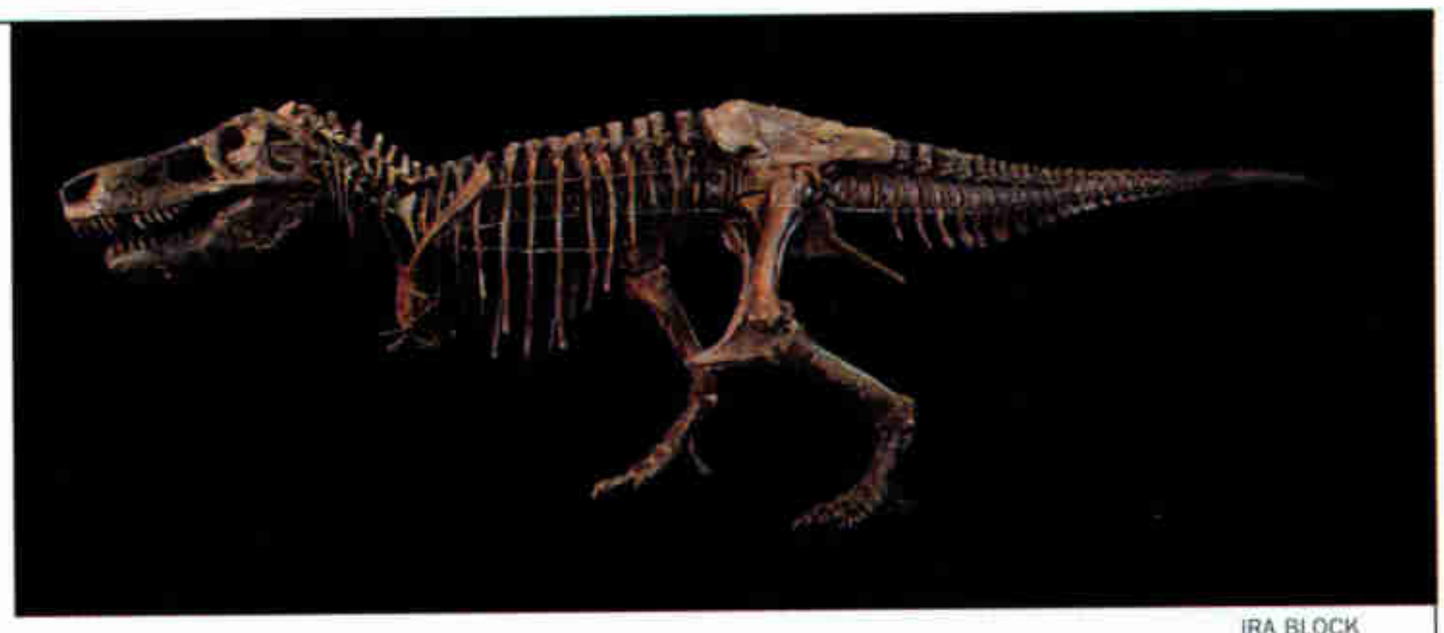
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Debut Sue

Noah must have been pleased that *Tyrannosaurus rex* and its mates had died out before the Flood.

JOHN WILBY
Brisbane, Australia



IRA BLOCK

First the Field Museum spent $8.36 million for what my dog buries in the backyard, and then Bruce Adolphe was commissioned to write a concerto to commemorate *T. rex* Sue, which would surely add ambience. We could economize here by using the Everly Brothers' "Wake Up Little Susie" instead.

J. GUEVARA
Puntarenas, Costa Rica

I'm puzzled by the current fashion among paleontologists of depicting bipedal dinosaurs such as *T. rex* with heads, spines, and bodies slunk low in a nearly horizontal stance. Dynamic, yes, but a marked contrast with the more upright posture of earlier portrayals. Reconstructed by the Field Museum, and beautifully fleshed out by your artists, the center of gravity for Sue is way out over its thorax and abdomen rather than its pelvis and legs. Ouch. As thus depicted, Sue would fall flat on its primordial face.

WALLACE R. HANSEN
Lakewood, Colorado

The vertical-trunk poses had the tails dragging on the ground. But trackways from bipedal dinosaurs do not show drag marks from the tail, and paleontologists now believe the tail was held out from the hip, acting as a counterbalance to the trunk and head.

While assigned to the U.S. Embassy in Paramaribo from 1986 to 1988, I was constantly surprised by their proud identification with things American.

ROBERT J. AUSTIN
Williamsburg, Virginia

Sierra Madre Pilgrimage

The poetic article tracing Carl Lumholtz's journeys is a welcome addition to our knowledge of the man buried in Pine Ridge Cemetery in our town. As a TB patient Lumholtz took the fresh air and rest treatment in a sanatorium on Baker Street.

MARY HOTALING
Saranac Lake, New York

Your article quoted Lumholtz as writing that he had seen "eight people with hair-lip." I wonder whether he wrote hair-lip or harelip. May I presume the latter? Most probably Lumholtz wrote in Norwegian, didn't he? Hair is hår in Norwegian, and hare is hare.

J. P. A. NICOLAI
Department of Plastic Surgery
University Hospital
Groningen, Netherlands

Lumholtz's book, Unknown Mexico, *was originally published in English in 1902. He did indeed write "hair-lip," an erroneous spelling of harelip, and we decided to be true to his text when we quoted him.*

Nicely dovetailing with the career of Carl Lumholtz is that of Thomas Baillie MacDougall, a Scottish-born naturalist and explorer who spent more than 40 years studying the flora, fauna, and cultures of two Mexican states, Oaxaca and Chiapas. He traveled into the Sierra Madre repeatedly from 1931 to 1973, almost always on foot. About 20 plant species have been named in their discoverer's honor, such as *Begonia macdougallii.* MacDougall's papers and photographs, like those of Lumholtz, are at the American Museum of Natural History.

JUDITH SAUL STIX
St. Louis, Missouri

In Focus: Golan Heights

This is the first time in years I have read about the Golan Heights in neutral terms in a Western magazine. You explained the sites and dates without the one-sided political rhetoric I find in the media. My Syrian family had to leave in the 1967 war and now lives in and around Damascus. I looked at the map and was saddened to see that our village, Ain-Fit,

WRITE TO FORUM

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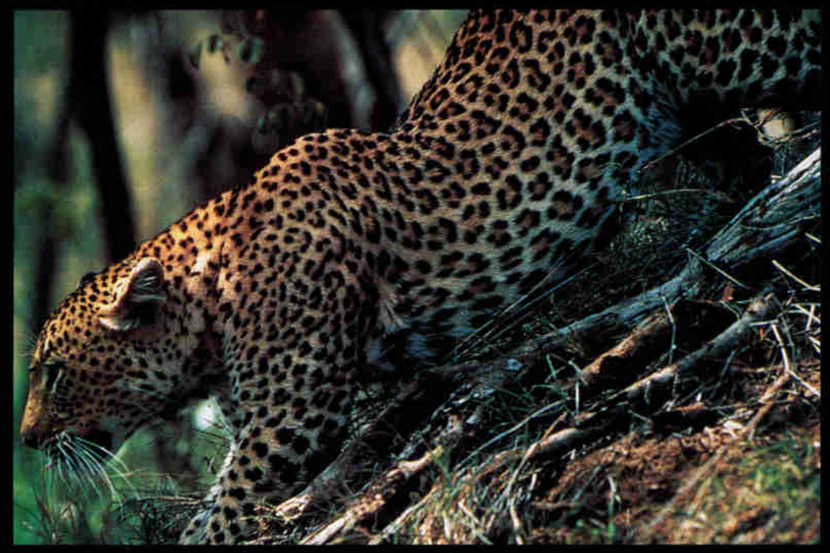
Black Rhinoceros, *cover*
Because their horns are highly valued as an aphrodisiac, the black rhino faces extinction.
Habitat: Grasslands and open forests in Africa; only small scattered populations remain, nearly all in wildlife sanctuaries
Surviving number: 2,600
Canon ad appeared April 1981 issue.

Western Lowland Gorilla, *far left*
Habitat: Tropical low-land forest in central west Africa
Surviving number: Fewer than 100,000
Canon ad appeared July 1999 issue.

Leopard, *top right*
Habitat: A variety of habitats in Africa, the Middle East and Asia
Surviving number: unknown
Canon ad appeared July 1992 issue.

Ring-tailed Lemur, *right*
Habitat: Deciduous and gallery forests and dry scrub in south Madagascar
Surviving number: Unknown
Canon ad appeared November 1995 issue.

Red Panda, *bottom right*
Habitat: Mountain forests from Nepal to northern Burma and into central China
Surviving number: 2,500
Canon ad appeared January 1988 issue.







The web of life is fragile.

The interconnections

vital. Every time a

species is lost, the

whole web is weakened.

When wildlife is in

danger,

so are we humans.

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Photographed by Elio Della Ferrera

WILDLIFE AS CANON SEES IT

Lifting powerful wings to the wind, a juvenile eastern imperial eagle launches from its hunting perch. The young eagle soars over open plains, scanning the ground for mammals such as sousliks, hamsters and hares. After four yearly moults the eagle attains adult plumage; for both males and females, this plumage is dark brown overall, with pale crown and neck and white scapulars. Mostly migratory, the eagles' range is vast but fragmented, extending from Europe to east China. For decades, eastern imperial eagle populations have been declining due to habitat loss and alteration, disturbance in breeding areas, and shooting and trapping.

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Eastern Imperial Eagle *(Aquila heliaca)*
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Habitat: Open plains, wooded steppes, semi-desert and foothills in Europe, the Middle East, Africa and Asia
Surviving number: Estimated at 2,000 pairs

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was included with those that were destroyed.

CAMILLA HUSSEIN-SCOTT
Albuquerque, New Mexico

The caption on the first page of the article incorrectly identifies the location of the photo as overlooking the Hula Valley. In fact, the picture was taken at Mount Bental overlooking the Syrian border and the town of Kuneitra. On a clear day the Hermon Mountain Range is spectacularly visible from this spot, as well as the outskirts of Damascus.

DON JACOBSON
Bikat Beit Hakerem, Israel

The maps on pages 106-107 ignore the fact that the Golan Heights are an integral part of Syria and label them as part of Israel. Israel's occupation of the Golan Heights in 1967 in no way prejudiced the legal status of the heights. In fact, UN Security Council resolutions 242 and 338 confirmed the inadmissibility of conquest of land by force and called on Israel to withdraw from the lands occupied in 1967, including the Syrian Golan Heights. We hope you will keep in mind that de facto Israeli occupation of the Golan Heights is in no way translated to juridical legitimacy.

ROSTOM AL-ZOU'BI
Chief of Mission
Embassy of the Syrian Arab Republic
Washington, D.C.

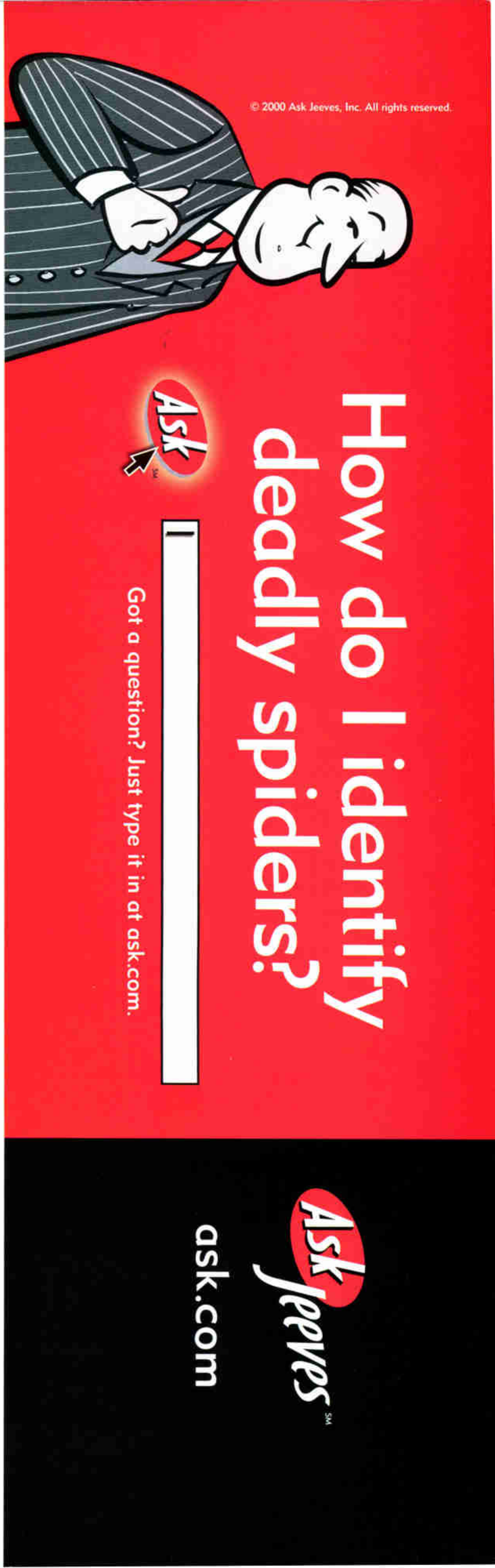
It is our policy to show de facto borders on NATIONAL GEOGRAPHIC *maps.*

With the recent withdrawal of Israeli forces from southern Lebanon and the death of President Assad, much has changed on the political map. Water and its availability, collection, distribution, and use within the region will strongly influence this map. The key to peace may not be so much the land but rather the water that flows over and under it.

H. CAMERON ROSS
Force Commander
United Nations Disengagement Observer Force
Camp Faouar on the Golan Heights
Syria

Jelly Bellies

I have studied leatherback sea turtles (major predators of jellyfish) for almost



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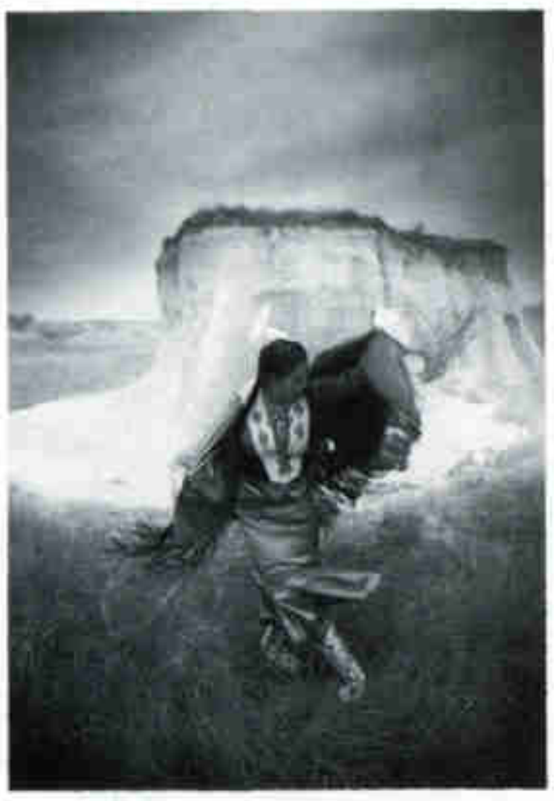
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FORUM

20 years. I can attest to our need to understand the role jellyfish play in the marine ecosystem and what may happen if jellyfish populations explode due to lack of predators. Leatherbacks are being killed in large numbers by accidental drowning in commercial gill net and longline fishing gear. Most of these fisheries are targeting pelagic fish such as swordfish and tuna, whose fry probably form a large portion of the pelagic jellyfish diet. By killing the leatherback, these commercial fisheries are threatening their own future. No leatherbacks, no swordfish.

SCOTT A. ECKERT
Senior Research Biologist
Hubbs-SeaWorld Research Institute
San Diego, California

The problem of controlling the jellyfish population in the Chesapeake Bay is simple: Eat the jellyfish! Jellyfish are a delicacy to the Chinese. They are first squeeze-dried, processed with a diluted acid, and then dried in the sun. They can be kept for months without spoiling.

JOSEPH TAN
Kuala Lumpur, Malaysia

Not all jellyfish can be eaten, and those in the Chesapeake are too lacking in texture to be appetizing when dried.

Indus Civilization

The article on the archaeology of old civilizations in the Indus Valley poses the question of their demise. Just as archaeologists have found that bricks have been destroyed by salt, so have irrigation engineers been convinced that soil salinity arising from flood irrigation of saline-susceptible soils permanently damaged those soils. The collapse of viable agriculture in these areas and subsequent development upstream destroyed the basis of the cities. Unfortunately the lessons of history are reluctantly learned. In Australia a similar problem exists. Should irrigation continue to be developed in lower reaches of the Murray Basin where salinity is a major problem, or should future development be diverted to more suitable land, even though the costs will be higher in the short term?

PAUL McGOWAN
Barnawartha, Australia

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THE PEOPLE, PLACES, AND

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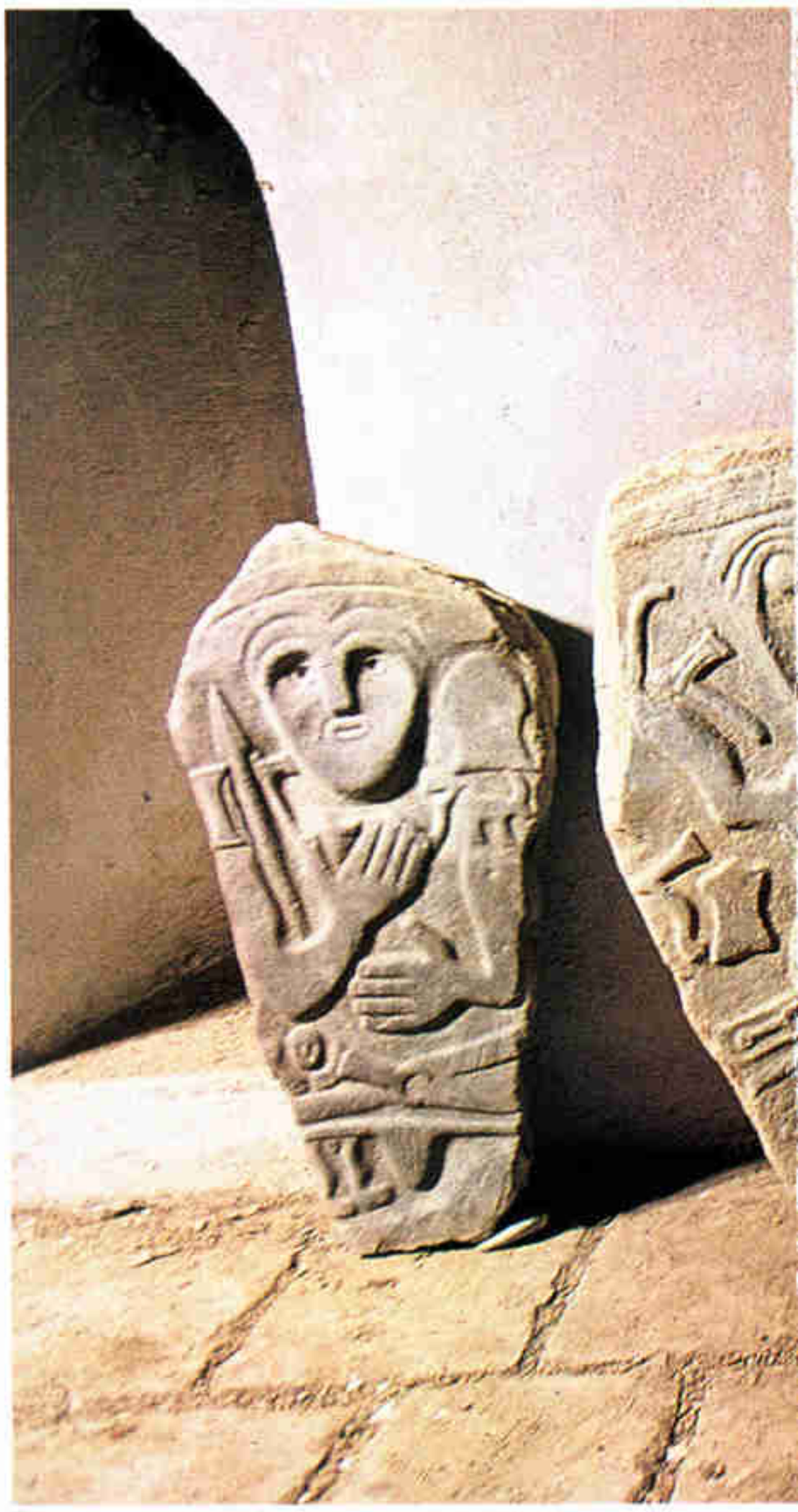
Great Stone Faces

Unearthing cultural mysteries in Turkey

An accidental discovery in remote Hakkâri, Turkey, has yielded treasures that may date back more than 3,000 years. A carved stone figure called a stela was unearthed by a local man digging for dirt to repair his mud-roofed house. The man notified Turkish authorities, who then called upon Veli Sevin (far right), professor of archaeology at Turkey's Çanakkale Onsekiz Mart University.

Further excavation (above) soon revealed 12 more stelae, representing powerful male and female figures. The 11 male figures hold drinking vessels and carry weapons, such as spears and daggers. Sevin thinks the stelae, which range from about two feet tall to more than ten feet, are funerary monuments for kings and nobles. It's an important find, Sevin believes. The style of the sculptures suggests "a very early connection between the Hakkâri region and the Eurasian steppes."







PAUL NICKLEN

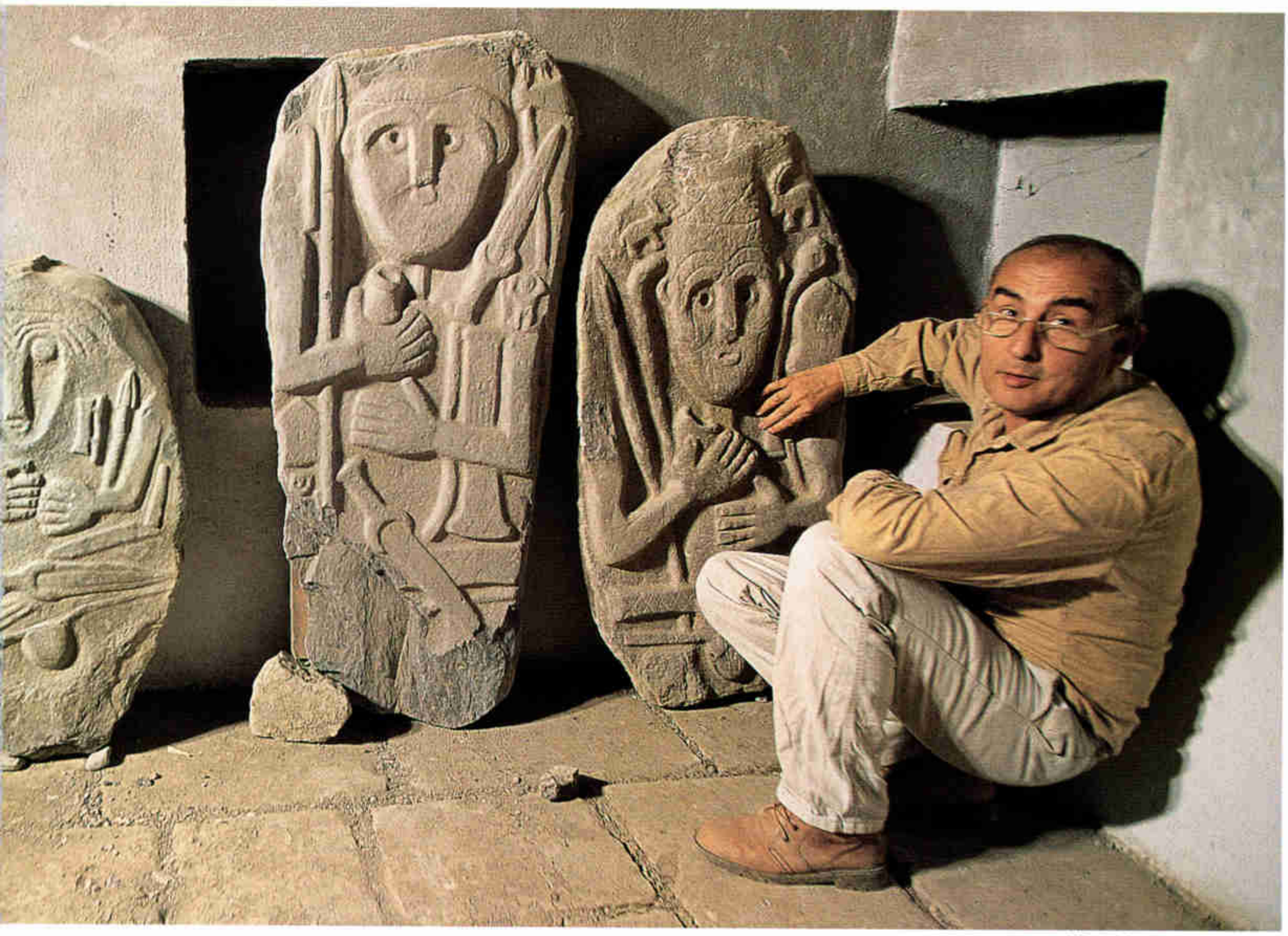
MARINE MAMMALS

Sea Lions' Plight

What has reduced Steller sea lions in Alaska waters from 260,000 in 1970 to only 45,000 or so today? Stellers now feed mainly on pollock, used to make imitation shellfish meat. Pollock overfishing is suspected by environmentalists, but scientists think the answer may have more to do with the quality of the sea lions' diet than the quantity. "Pollock are nutritionally deficient," says zoologist Andrew Trites of the University of British Columbia, "and are an overabundant part of their diet."

APHICA

CREATURES OF OUR UNIVERSE



MEHMET GULBIZ (ABOVE AND LEFT)



JAMES P. BLAIR (ABOVE); ART BY MATT FREY

CONSERVATION

A Boost to Big Trees

A home of forest monarchs, some of them 30 feet in diameter and 3,000 years old, gained protection last April when 328,000 acres of Sequoia National Forest in California were declared a national monument. Although giant sequoias, which can weigh as much as 600 tons, were already protected, commercial logging of other conifers in the monument will be phased out. One of several new national monuments created this year, Sequoia brings the total to more than 180, safeguarding some 70 million acres.

ALMANAC

October

The autumn sky becomes a highway for North American birds of prey migrating south. In Mexico's Veracruz state the birds are funneled between the Gulf of Mexico and mountains 40 miles to the west. In between, observers count more than four million raptors each fall. Most of the world's 200,000 Mississippi kites—like this one—pass through Veracruz.





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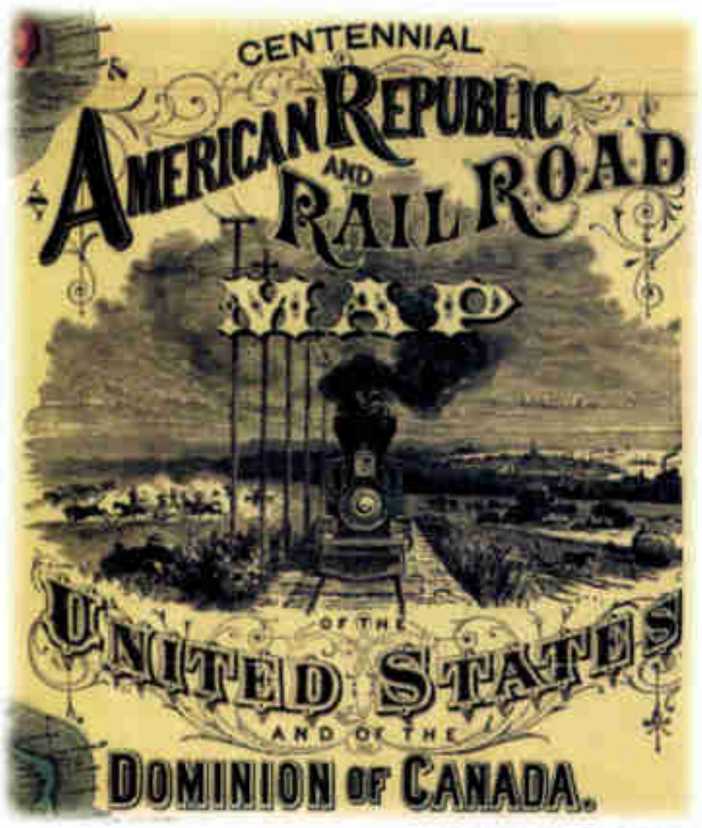
DISASTER RELIEF

Photo Finish to Flood

Half a million Mozambicans were displaced by torrential rain and floods last February and March. To reunite separated family members along the Limpopo River, Save the Children workers used disposable and Polaroid cameras to photograph victims like these four children at Samora Machel camp. The pictures then were circulated in other camps. The photos aided many reunions, perhaps including these youngsters, who all found their way home. The technique was also used in Kosovo.



CHRISTINE KNUDSEN



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CARTOGRAPHY

Mapping Tracks

A steam locomotive stitches together East and West in this title panel from an 1875 map of American railroads. From the 1830s on, railroad maps by the hundreds documented the rapid spread of the iron horse across the North American continent. At first these maps served utilitarian purposes. But starting in 1850, railroad companies received huge government land grants. Eager to sell land, the companies printed elaborate promotional maps, which sometimes took liberties with locations of stations and other features to increase the allure of the property.

MORE ON OUR WEBSITE

View railroad maps from the Library of Congress collection at **nationalgeographic.com/maps/geographica.**

ANTHROPOLOGY

Heads Up for First Fabrics



Hairstyle or hat? Patterns on the heads of 26,000-year-old Venus sculptures such as those found in Willendorf, Austria (left), and Brassempouy, France (right), have always been assumed to represent hair. Now anthropologist Olga Soffer of the University of Illinois at Urbana-Champaign proposes that the figurines are wearing replicas of hats. She and James Adovasio of Mercyhurst College recently found sewing tools and impressions of interlaced fibers on clay shards at Upper Paleolithic sites. Her theory would push back the first known textile use some 20,000 years.



STEVE HOLLAND, UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

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ENVIRONMENT

Backyard Barrel Burning

Out in the country, pollutants add up

In rural America, where landfills and incinerators are sparse, an estimated 20 million people burn their trash outdoors, some in old 55-gallon oil drums. How much pollution goes up in smoke, the EPA wondered? A study analyzed barrel-burned trash, which included paper, cardboard, plastic, tin cans, food waste, and glass. The result: Barrels may release as many dioxins as did all municipal incinerators in 1995, before the EPA tightened incinerator rules. "Backyard burning is one more factor that goes into the pollution mix," says the EPA's Dwain Winters, adding that only state restrictions, not federal, now apply.



ART BY RICHARD DOWNS



LANDSAT IMAGE PRODUCED BY ROBERT E. CRIPPEN, JET PROPULSION LABORATORY, NASA

CONSERVATION

Wild Side of L.A.

Groups buying corridor as an animal haven

Surrounded by more than five million people, an ecosystem in the Los Angeles Basin remains surprisingly intact. Not far from downtown L.A., the 30-mile-long Puente–Chino Hills Wildlife Corridor harbors mule deer, bobcats, foxes, nearly a hundred species of breeding birds, and a few mountain lions. Conservationists have purchased almost half the corridor's 40,000 acres.

The ecosystem includes the hills above, valuable real estate prized by developers. "We have bought several important parcels owned by oil companies in the hills, and we're still negotiating," says Bev Perry of the corridor's Conservation Authority. "There have been wells up there since about 1900, and some are still producing."

TECHNOLOGY

Fool's Gold

Congress wanted a gold-colored metal for the new Sacagawea dollar, but scientists couldn't find one that vending machines would accept. They had almost given up when they tried pink-toned copper manganese, which turns gold when zinc is added. Vending machines were happy—and so was Capitol Hill.



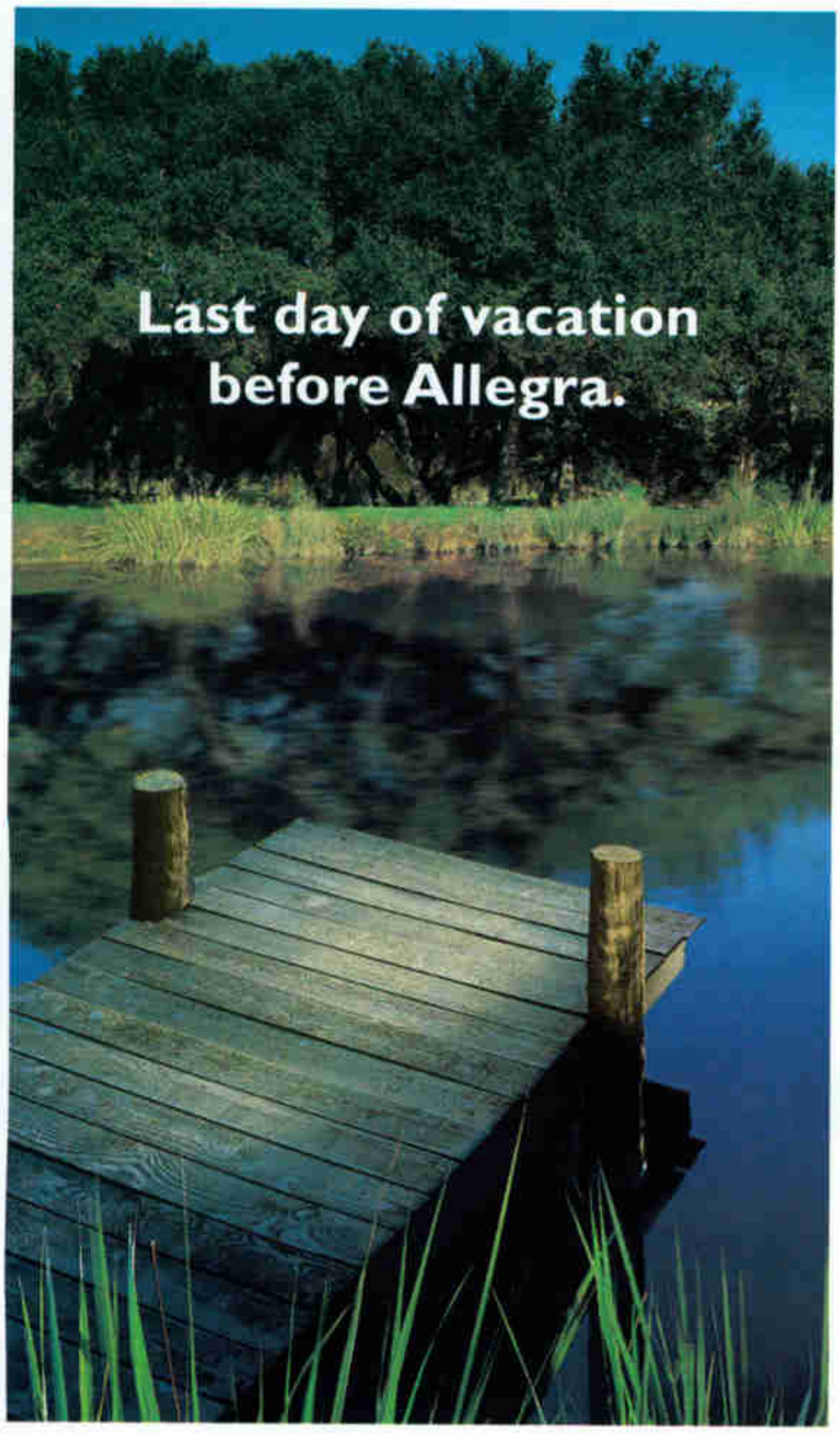
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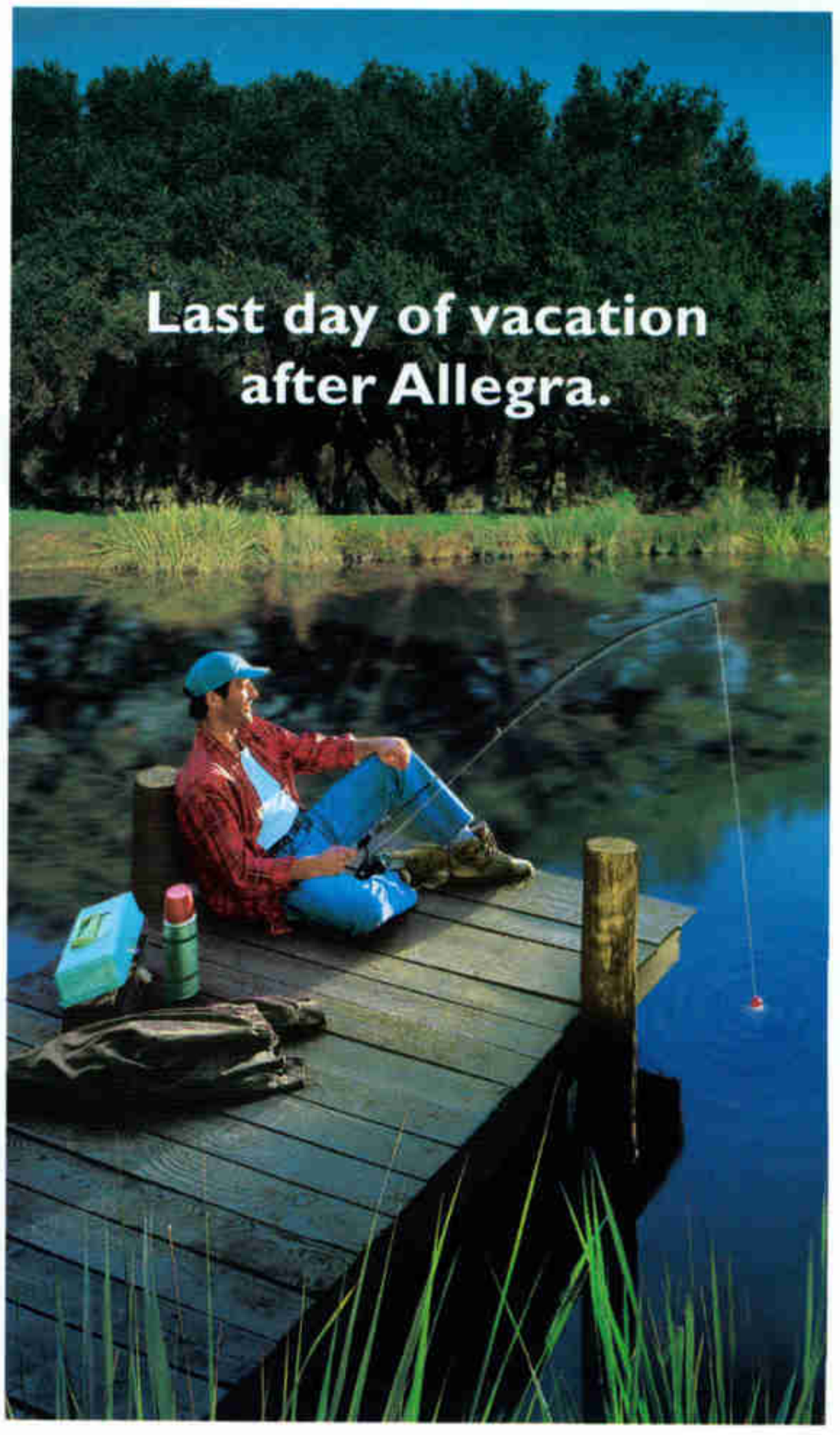
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Brief Summary of Prescribing Information as of February 2000

ALLEGRA®
(fexofenadine hydrochloride)
Capsules and Tablets

INDICATIONS AND USAGE

Seasonal Allergic Rhinitis

ALLEGRA is indicated for the relief of symptoms associated with seasonal allergic rhinitis in adults and children 6 years of age and older. Symptoms treated effectively were sneezing, rhinorrhea, itchy nose/palate/throat, itchy/watery/red eyes.

Chronic Idiopathic Urticaria

ALLEGRA is indicated for treatment of uncomplicated skin manifestations of chronic idiopathic urticaria in adults and children 6 years of age and older. It significantly reduces pruritus and the number of wheals.

CONTRAINDICATIONS

ALLEGRA is contraindicated in patients with known hypersensitivity to any of its ingredients.

PRECAUTIONS

Drug Interaction with Erythromycin and Ketoconazole

Fexofenadine hydrochloride has been shown to exhibit minimal (ca. 5%) metabolism. However, co-administration of fexofenadine hydrochloride with ketoconazole and erythromycin led to increased plasma levels of fexofenadine hydrochloride. Fexofenadine hydrochloride had no effect on the pharmacokinetics of erythromycin and ketoconazole. In two separate studies, fexofenadine hydrochloride 120 mg twice daily (two times the recommended twice daily dose) was co-administered with erythromycin 500 mg every 8 hours or ketoconazole 400 mg once daily under steady-state conditions to normal, healthy volunteers (n=24, each study). No differences in adverse events or QT_C interval were observed when patients were administered fexofenadine hydrochloride alone or in combination with erythromycin or ketoconazole. The findings of these studies are summarized in the following table:

Effects on steady-state fexofenadine hydrochloride pharmacokinetics after 7 days of co-administration with fexofenadine hydrochloride 120 mg every 12 hours (two times the recommended twice daily dose) in normal volunteers (n=24)

Concomitant Drug	C_{maxSS} *(Peak plasma concentration)*	$AUC_{SS(0\text{-}12h)}$ *(Extent of systemic exposure)*
Erythromycin (500 mg every 8 hrs)	+82%	+109%
Ketoconazole (400 mg once daily)	+135%	+164%

The changes in plasma levels were within the range of plasma levels achieved in adequate and well-controlled clinical trials.

The mechanism of these interactions has been evaluated in *in vitro*, *in situ*, and *in vivo* animal models. These studies indicate that ketoconazole or erythromycin co-administration enhances fexofenadine gastrointestinal absorption. *In vivo* animal studies also suggest that in addition to increasing absorption, ketoconazole decreases fexofenadine hydrochloride gastrointestinal secretion, while erythromycin may also decrease biliary excretion.

Drug Interactions with Antacids

Administration of 120 mg of fexofenadine hydrochloride (2 x 60 mg capsule) within 15 minutes of an aluminum and magnesium containing antacid (Maalox®) decreased fexofenadine AUC by 41% and C_{max} by 43%. ALLEGRA should not be taken closely in time with aluminum and magnesium containing antacids.

Carcinogenesis, Mutagenesis, Impairment of Fertility

The carcinogenic potential and reproductive toxicity of fexofenadine hydrochloride were assessed using terfenadine studies with adequate fexofenadine hydrochloride exposure (based on plasma area-under-the-concentration vs. time [AUC] values). No evidence of carcinogenicity was observed in an 18-month study in mice and in a 24-month study in rats at oral doses up to 150 mg/kg of terfenadine (which led to fexofenadine exposures that were respectively approximately 3 and 5 times the exposure from the maximum recommended daily oral dose of fexofenadine hydrochloride in adults and children).

In *in vitro* (Bacterial Reverse Mutation, CHO/HGPRT Forward Mutation, and Rat Lymphocyte Chromosomal Aberration assays) and *in vivo* (Mouse Bone Marrow Micronucleus assay) tests, fexofenadine hydrochloride revealed no evidence of mutagenicity.

In rat fertility studies, dose-related reductions in implants and increases in postimplantation losses were observed at an oral dose of 150 mg/kg of terfenadine (which led to fexofenadine hydrochloride exposures that were approximately 3 times the exposure of the maximum recommended daily oral dose of fexofenadine hydrochloride in adults).

Pregnancy

Teratogenic Effects: Category C. There was no evidence of teratogenicity in rats or rabbits at oral doses of terfenadine up to 300 mg/kg (which led to fexofenadine exposures that were approximately 4 and 31 times, respectively, the exposure from the maximum recommended daily oral dose of fexofenadine in adults).

There are no adequate and well controlled studies in pregnant women. Fexofenadine should be used during pregnancy only if the potential benefit justifies the potential risk to the fetus.

Nonteratogenic Effects. Dose-related decreases in pup weight gain and survival were observed in rats exposed to an oral dose of 150 mg/kg of terfenadine (approximately 3 times the maximum recommended daily oral dose of fexofenadine hydrochloride in adults based on comparison of fexofenadine hydrochloride AUCs).

Nursing Mothers

There are no adequate and well-controlled studies in women during lactation. Because many drugs are excreted in human milk, caution should be exercised when fexofenadine hydrochloride is administered to a nursing woman.

Pediatric Use

The recommended dose in patients 6 to 11 years of age is based on cross-study comparison of the pharmacokinetics of ALLEGRA in adults and pediatric patients and on the safety profile of fexofenadine hydrochloride in both adult and pediatric patients at doses equal to or higher than the recommended doses.

The safety of ALLEGRA tablets at a dose of 30 mg twice daily has been demonstrated in 438 pediatric patients 6 to 11 years of age in two placebo-controlled 2-week seasonal allergic rhinitis trials. The safety of ALLEGRA for the treatment of chronic idiopathic urticaria in patients 6 to 11 years of age is based on cross-study comparison of the pharmacokinetics of ALLEGRA in adult and pediatric patients and on the safety profile of fexofenadine in both adult and pediatric patients at doses equal to or higher than the recommended dose.

The effectiveness of ALLEGRA for the treatment of seasonal allergic rhinitis in patients 6 to 11 years of age was demonstrated in one trial (n=411) in which ALLEGRA tablets 30 mg twice daily significantly reduced total symptom scores compared to placebo, along with extrapolation of demonstrated efficacy in patients ages 12 years and above, and the pharmacokinetic comparisons in adults and children. The effectiveness of ALLEGRA for the treatment of chronic idiopathic urticaria in patients 6 to 11 years of age is based on an extrapolation of the demonstrated efficacy of ALLEGRA in adults with this condition and the likelihood that the disease course, pathophysiology and the drug's effect are substantially similar in children to that of adult patients.

The safety and effectiveness of ALLEGRA in pediatric patients under 6 years of age have not been established.

Geriatric Use

Clinical studies of ALLEGRA tablets and capsules did not include sufficient numbers of subjects aged 65 years and over to determine whether this population responds differently from younger patients. Other reported clinical experience has not identified differences in responses between the geriatric and younger patients. This drug is known to be substantially excreted by the kidney, and the risk of toxic reactions to this drug may be greater in patients with impaired renal function. Because elderly patients are more likely to have decreased renal function, care should be taken in dose selection, and may be useful to monitor renal function. (See CLINICAL PHARMACOLOGY).

ADVERSE REACTIONS

Seasonal Allergic Rhinitis

Adults. In placebo-controlled seasonal allergic rhinitis clinical trials in patients 12 years of age and older, which included 2461 patients receiving fexofenadine hydrochloride capsules at doses of 20 mg to 240 mg twice daily, adverse events were similar in fexofenadine hydrochloride and placebo-treated patients. All adverse events that were reported by greater than 1% of patients who received the recommended daily dose of fexofenadine hydrochloride (60 mg capsules twice daily), and that were more common with fexofenadine hydrochloride than placebo, are listed in Table 1.

In a placebo-controlled clinical study in the United States, which included 570 patients aged 12 years and older receiving fexofenadine hydrochloride tablets at doses of 120 or 180 mg once daily, adverse events were similar in fexofenadine hydrochloride and placebo-treated patients. Table 1 also lists adverse experiences that were reported by greater than 2% of patients treated with fexofenadine hydrochloride tablets at doses of 180 mg once daily and that were more common with fexofenadine hydrochloride than placebo.

The incidence of adverse events, including drowsiness, was not dose-related and was similar across subgroups defined by age, gender, and race.

Table 1

Adverse experiences in patients ages 12 years and older reported in placebo-controlled seasonal allergic rhinitis clinical trials in the United States

Twice daily dosing with fexofenadine capsules at rates of greater than 1%

Adverse experience	*Fexofenadine 60 mg Twice Daily (n=679)*	*Placebo Twice Daily (n=671)*
Viral Infection (cold, flu)	2.5%	1.5%
Nausea	1.6%	1.5%
Dysmenorrhea	1.5%	0.3%
Drowsiness	1.3%	0.9%
Dyspepsia	1.3%	0.6%
Fatigue	1.3%	0.9%

Once daily dosing with fexofenadine hydrochloride tablets at rates of greater than 2%

Adverse experience	*Fexofenadine 180 mg once daily (n=283)*	*Placebo (n=293)*
Headache	10.6%	7.5%
Upper Respiratory Tract Infection	3.2%	3.1%
Back Pain	2.8%	1.4%

The frequency and magnitude of laboratory abnormalities were similar in fexofenadine hydrochloride and placebo-treated patients.

Pediatric. Table 2 lists adverse experiences in patients aged 6 to 11 years of age which were reported by greater than 2% of patients treated with fexofenadine hydrochloride tablets at a dose of 30 mg twice daily in placebo-controlled seasonal allergic rhinitis studies in the United States and Canada that were more common with fexofenadine hydrochloride than placebo.

Table 2

Adverse experiences reported in placebo-controlled seasonal allergic rhinitis studies in pediatric patients ages 6 to 11 in the United States and Canada at rates of greater than 2%

Adverse experience	*Fexofenadine 30 mg twice daily (n=209)*	*Placebo (n=229)*
Headache	7.2%	6.6%
Accidental Injury	2.9%	1.3%
Coughing	3.8%	1.3%
Fever	2.4%	0.9%
Pain	2.4%	0.4%
Otitis Media	2.4%	0.0%
Upper Respiratory Tract Infection	4.3%	1.7%

Chronic Idiopathic Urticaria

Adverse events reported by patients 12 years of age and older in placebo-controlled chronic idiopathic urticaria studies were similar to those reported in placebo-controlled seasonal allergic rhinitis studies. In placebo-controlled chronic idiopathic urticaria clinical trials, which included 726 patients 12 years of age and older receiving fexofenadine hydrochloride tablets at doses of 20 to 240 mg twice daily, adverse events were similar in fexofenadine hydrochloride and placebo-treated patients. Table 3 lists adverse experiences in patients aged 12 years and older which were reported by greater than 2% of patients treated with fexofenadine hydrochloride 60 mg tablets twice daily in controlled clinical studies in the United States and Canada and that were more common with fexofenadine hydrochloride than placebo. The safety of fexofenadine hydrochloride in the treatment of chronic idiopathic urticaria in pediatric patients 6 to 11 years of age is based on the safety profile of fexofenadine hydrochloride in adults and adolescent patients at doses equal to or higher than the recommended dose (see Pediatric Use).

Table 3

Adverse experiences reported in patients 12 years and older in placebo-controlled chronic idiopathic urticaria studies in the United States and Canada at rates of greater than 2%

Adverse experience	*Fexofenadine 60 mg twice daily (n=186)*	*Placebo (n=178)*
Back Pain	2.2%	1.1%
Sinusitis	2.2%	1.1%
Dizziness	2.2%	0.6%
Drowsiness	2.2%	0.0%

OVERDOSAGE

Reports of fexofenadine hydrochloride overdose have been infrequent and contain limited information. However, dizziness, drowsiness, and dry mouth have been reported. Single doses of fexofenadine hydrochloride up to 800 mg (six normal volunteers at this dose level), and doses up to 690 mg twice daily for 1 month (three normal volunteers at this dose level) or 240 mg once daily for 1 year (234 normal volunteers at this dose level) were administered without the development of clinically significant adverse events as compared to placebo.

In the event of overdose, consider standard measures to remove any unabsorbed drug. Symptomatic and supportive treatment is recommended.

Hemodialysis did not effectively remove fexofenadine hydrochloride from blood (1.7% removed) following terfenadine administration.

No deaths occurred at oral doses of fexofenadine hydrochloride up to 5000 mg/kg in mice (110 times the maximum recommended daily oral dose in adults and 200 times the maximum recommended daily oral dose in children based on mg/m^2) and up to 5000 mg/kg in rats (230 times the maximum recommended daily oral dose in adults and 400 times the maximum recommended daily oral dose in children based on mg/m^2). Additionally, no clinical signs of toxicity or gross pathological findings were observed. In dogs, no evidence of toxicity was observed at oral doses up to 2000 mg/kg (300 times the maximum recommended daily oral dose in adults and 530 times the maximum recommended daily oral dose in children based on mg/m^2).

Prescribing Information as of February 2000

Aventis Pharmaceuticals Inc.
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US Patents 4,254,129; 5,375,693; 5,578,610

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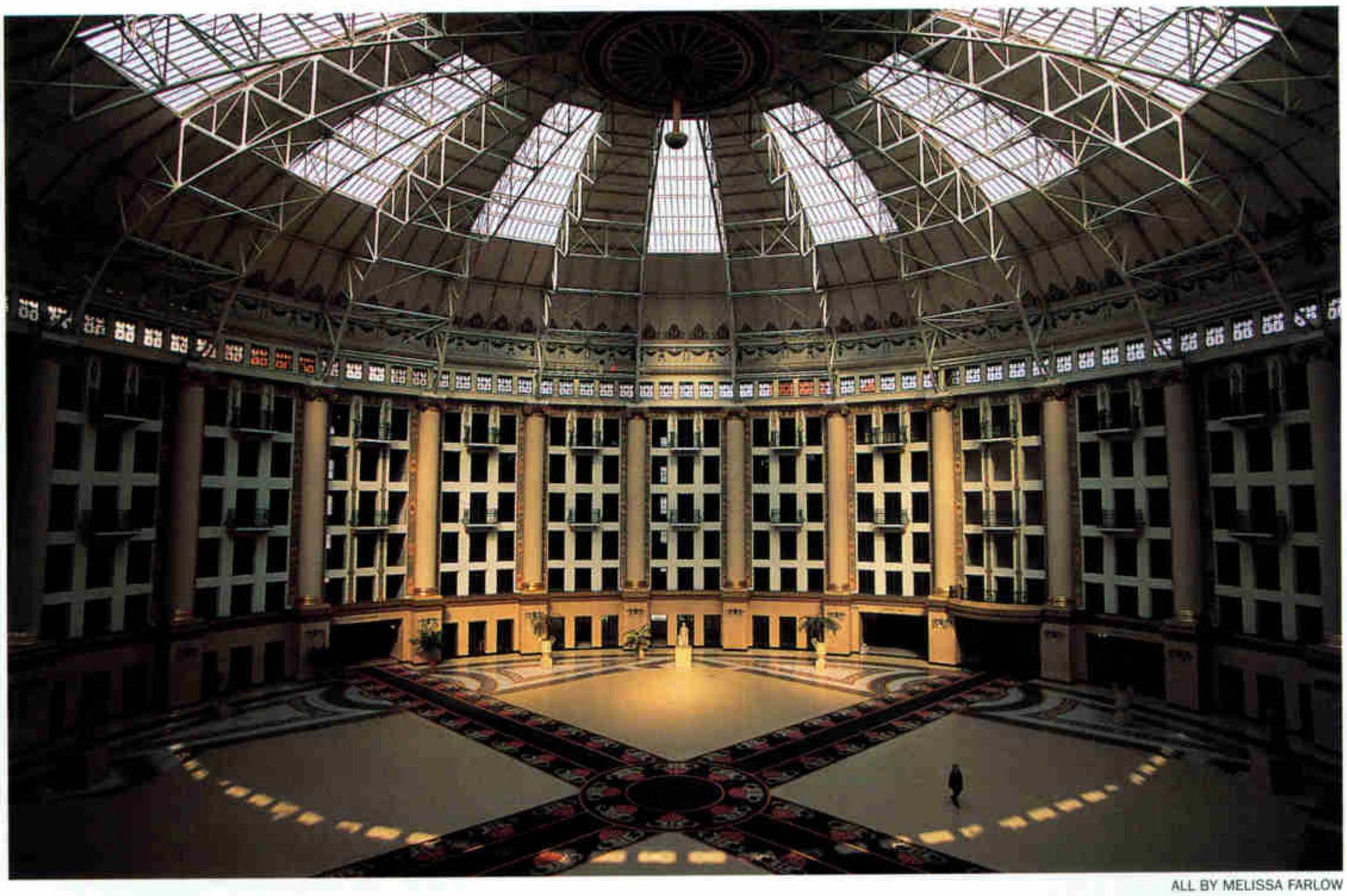
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PRESERVATION

New Hope For a Legend

A luxury spa in the past, hotel seeks a future



In its heyday in the early decades of the 20th century the West Baden Springs Hotel in southern Indiana ranked among the toniest of resorts. The wealthy, the famous, the notorious—from Helen Keller to Al Capone—visited, some to take the waters of its mineral springs, others to bask in its luxury under the huge atrium dome, larger than that of the U.S. Capitol. But the stock market crash of 1929 sent the hotel into decline; its clientele shrank from 700 guests a day to fewer than 20. In 1934 its desperate owner finally gave it to the Jesuits, who used it as a seminary. Three decades later it became a private college branch; then from 1983 it stood all but vacant. By the 1990s, when a wall collapsed, it seemed doomed.

"We were sitting here watching a national historic landmark decline," says Tina Connor of the nonprofit Historic Landmarks Foundation of Indiana. "It's our job to save places like this."

The foundation quickly spent





$200,000 to study and stabilize the building. Acquiring the property in 1996, it began restoration with funds from the Cook Group, a preservation-minded Indiana family business.

Most of the 34.5 million dollars has gone into the main building, with its six-story atrium (top) and intricate mosaic tile floor (left). "You see people's jaws drop when they walk in," Connor says. Workers have also restored the front gate (far left). Graffiti-marred paintings of angels (above) in a chamber at the top of the dome remain untouched, awaiting decisions by a future purchaser. "We've had some tire kickers but no buyers. It's a challenge," Connor says.

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PAUL DEBEVEC, UNIVERSITY OF CALIFORNIA, BERKELEY

ART AND TECHNOLOGY

Digitizing "David"

Michelangelo enters the computer age

A Stanford computer group points a laser beam, mounted on a customized gantry, at Michelangelo's 23-foot-tall "David" in the Galleria dell' Accademia in Florence, Italy. Using the beam's measurements, the team is creating a three-dimensional computerized portrait of the marble sculpture to let experts "see" it in otherwise unseeable ways: A visitor would have to be outside looking through museum walls to view this profile (right). The statue's gaze is anatomically distorted when seen head-on, the exercise revealed. The Stanford group is also pushing the state of the art in computer graphics. "This model, requiring 32 gigabytes, will be one hundred times larger than any geometric computer model yet created with 3-D scanning," says Marc Levoy, the team leader.



MARC LEVOY, STANFORD UNIVERSITY



NGS RESEARCH GRANT

Costly Heavy Metal

Abandoned mines pock the Colorado Rockies, legacy of a long search for gold, silver, and many other metals—including cadmium. Moved into surface soil by mining and taken up by plants, cadmium has contaminated the region's white-tailed ptarmigan population, according to ecologist James R. Larison of Cornell University.

"Ptarmigan accumulate cadmium in their kidneys and sustain renal damage," he says. This causes calcium loss, and many birds suffer broken bones in their legs and wings. Larison believes that cadmium may also be affecting other plant-eaters, including elk, moose, beavers, and snowshoe hares.

JAMES R. LARISON

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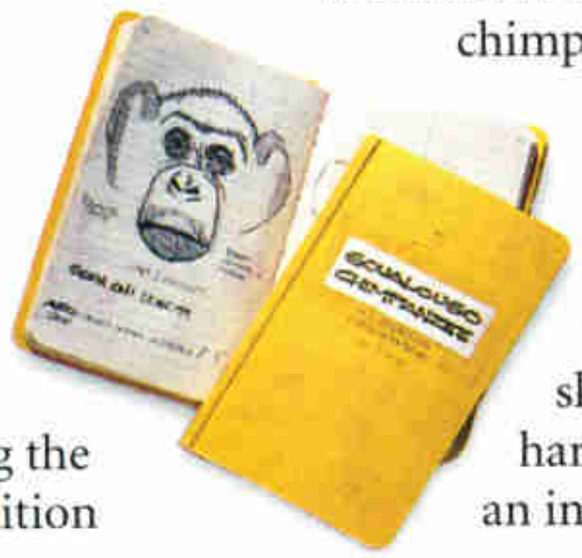
NATIONAL GEOGRAPHIC PHOTOGRAPHER MICHAEL NICHOLS

Dad, I Presume?

Meeting in the jungle unites father and son

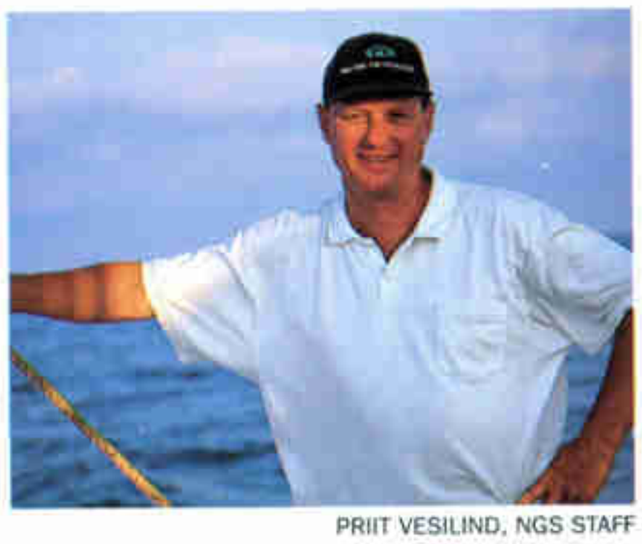
After months of hiking in central Africa's forests and swamps, photographer Michael "Nick" Nichols got a rare treat at an unimaginably remote site in the Republic of the Congo's Goualougo Triangle: a visit from his son Ian (above, at left). Ian, then 18 and a recent high school graduate, was volunteering at an orphan gorilla project in Gabon and took a break to see his father, who was chronicling the Megatransect expedition (pages 2-29). "I had lost 30 pounds, cut my hair, and grown a semblance of a beard," says Nick, at right. "This was a portrait for Mom and Grandmom."

Another kind of portrait in a yellow sketchbook (below) helped researcher Dave Morgan compile a census of the Goualougo's chimpanzees. "Each has distinctive characteristics such as ear shape," Morgan says. "Without the sketches it would be hard to know if I'd seen an individual before."

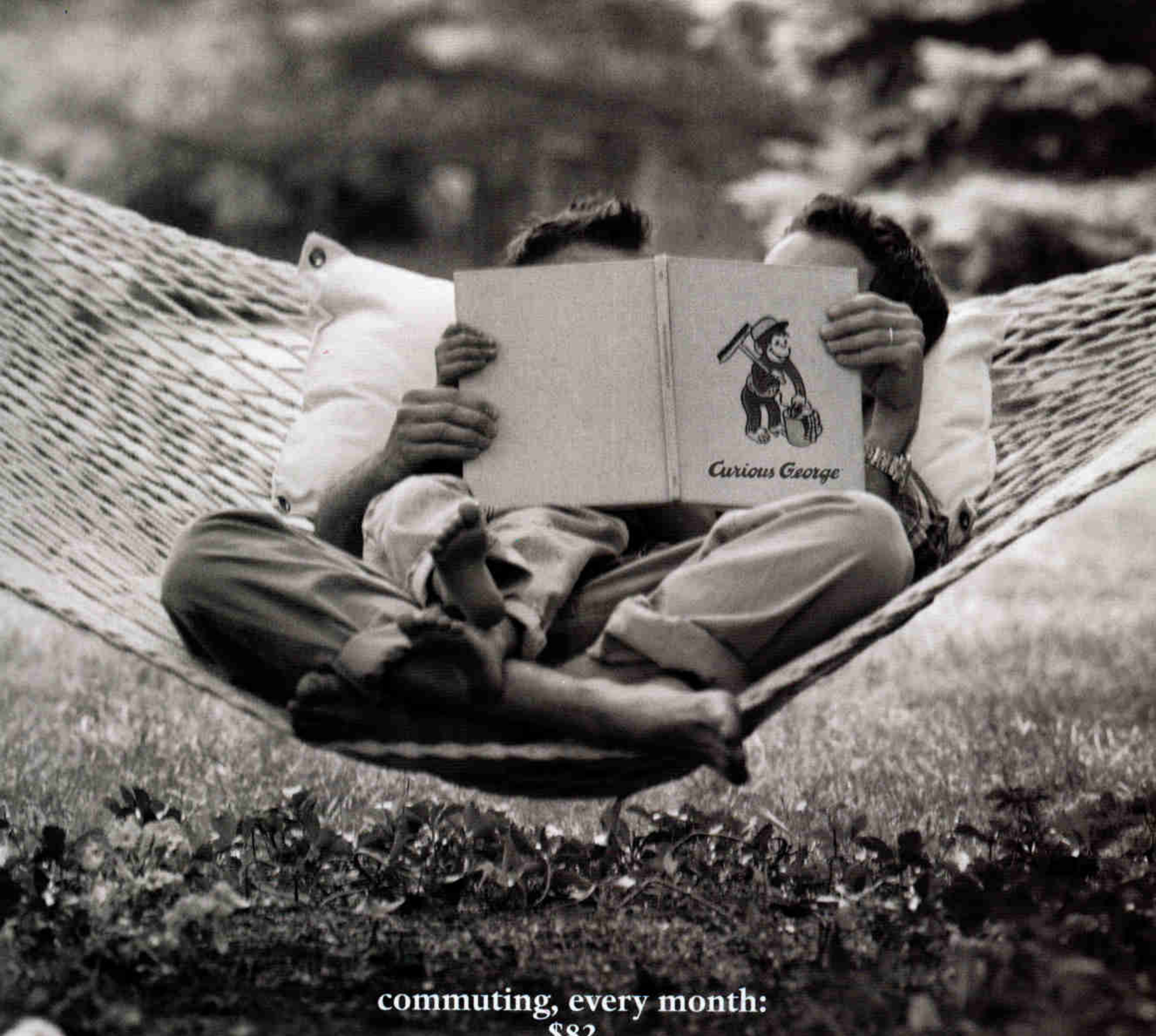


EXPLORER-IN-RESIDENCE

"There is more history in the deep sea than in all the museums in the world combined," says explorer and oceanographer Robert D. Ballard. During more than a hundred deep-sea expeditions he has discovered numerous sunken ships, including his most famous find, R.M.S. *Titanic*, in 1985.



PRIIT VESILIND, NGS STAFF



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A Presence at Yalta

Geographic maps go to war



CORBIS/BETTMANN; PATRICK WARD (BELOW)

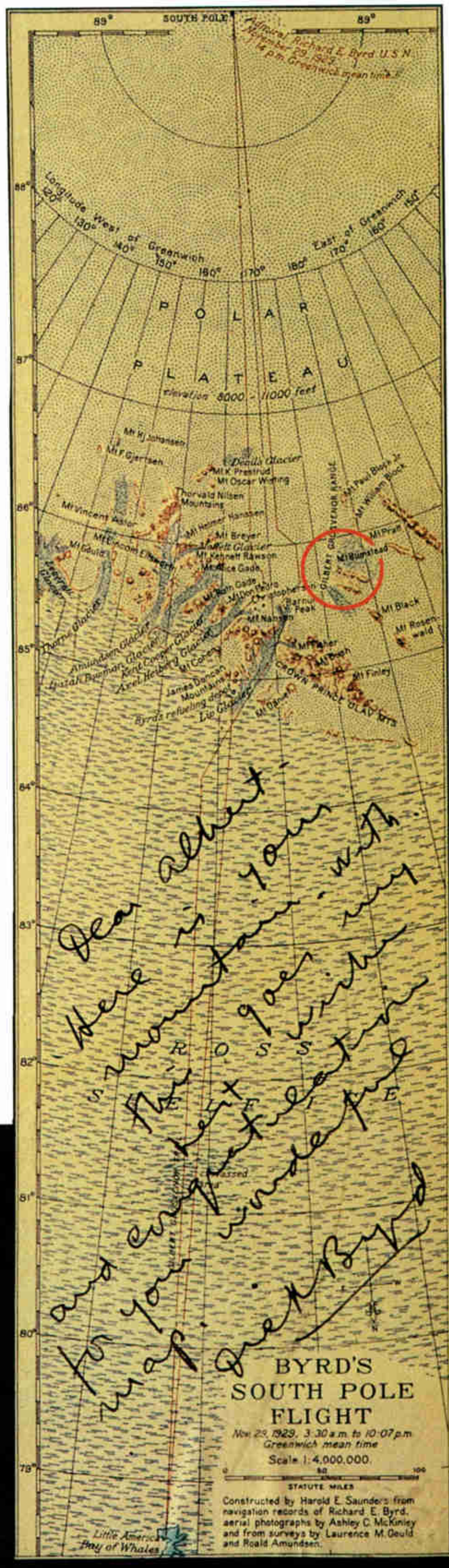
British Prime Minister Winston Churchill was noted for hauling around maps during World War II to track the war's progress. Some of them came from the Geographic, like this map of Germany and its approaches (below) on display in London's Cabinet War Rooms. Churchill (above, at left), who had his own personal mapkeeper, took the map to the Yalta Conference in February 1945, where he met with U.S. President Franklin D. Roosevelt (at center) and Soviet Premier Joseph Stalin (at right) to plan postwar Europe.

Markings on a plastic overlay show proposed Allied occupation zones in Germany and Austria, along with alterations negotiated at the conference.



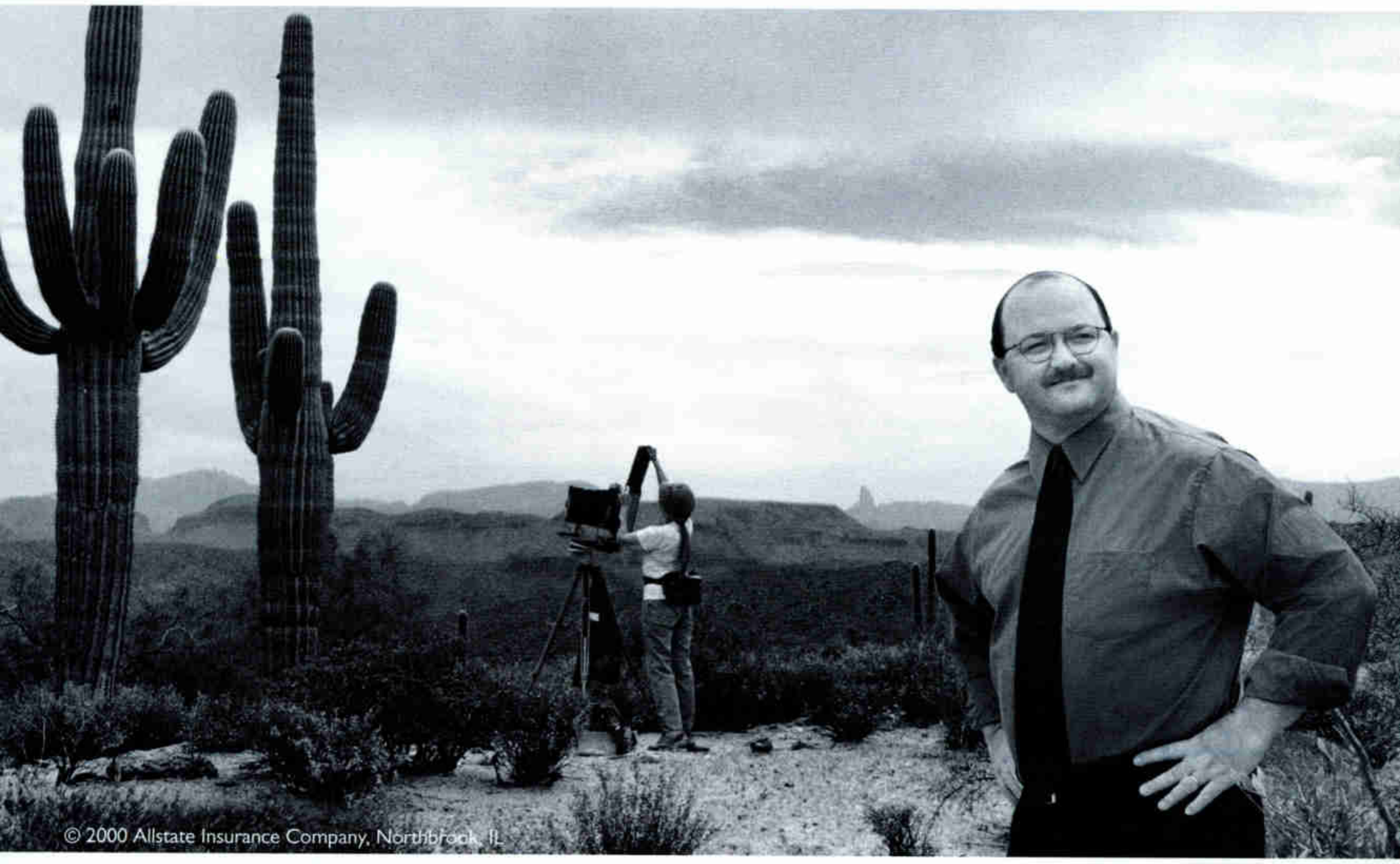
A Map Comes Home

"Dear Albert, Here is your mountain," wrote Adm. Richard E. Byrd on this 1932 Geographic map of his 1929 flight to the South Pole. Albert H. Bumstead, the Society's Chief Cartographer, had created the sun-compass Byrd used in polar travel; in return, the explorer named an Antarctic mountain, ringed in red, Mount Bumstead. Bumstead's family hung the signed map in their New Hampshire home. There it remained until last year, when his grandsons offered it to the Society. It now resides in our archives.



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LORI BUTTERFIELD

NGS EXPEDITIONS GRANT

Out in the Cold

A "real winter wimp," National Geographic Television producer Lori Butterfield (below) calls herself. But when Gustavus "Gus" McLeod (above, at left) of Gaithersburg, Maryland, set off in his 1939 Stearman to attempt the first open-cockpit biplane flight to the North Pole—funded in part by the Society's Expeditions Council—she didn't wimp out. Last April Lori and cameraman Duane Empey (above) tracked McLeod in chase planes as he hopscotched to the Pole.

"It's a wonderful story, an adventure for the common man," she says. "But up there he really could die. I was stressed every day until I saw Gus was OK."



ROBERT THOMASSEN

Deep Insights

GEOGRAPHIC researchers are known for going to the ends of the Earth to verify stories. Researcher Carol Kaufmann, for example, went to the Pacific Ocean floor. On R.V. *Atlantis* with staff writer Lynne Warren for an 18-day science voyage to 9° N for this issue's story on sea vents, Carol plunged a mile and a half in the submersible *Alvin* (below) to investigate vent communities firsthand.



ROBERT LEE WILLIAMS

100 YEARS AGO

October 1900

"The darkest horror of American history has fallen on our southern coast. . . . Out of the awful chaos spring the twin progeny of catastrophe, begotten of the best and the worst of humanity—Heroism, clad gloriously in helpfulness and self-abnegation, and Ghoulism, shrouded vilely in cowardice and unholy greed."

—W J McGee, reporting in the GEOGRAPHIC on the Galveston, Texas, hurricane of 1900.

Plant Champion

The healing power of plants drives Nat Quansah, an ethnobotanist in Madagascar. Many of the island's more than 10,000 plant species —80 percent of them endemic—are used in traditional medicine. But deforestation is a threat. To heighten awareness, Quansah opened a clinic in 1994, where nearly 6,000 patients have been treated with both plants and Western medicine. "Traditional healers have a sixth sense," he says. Nominated by the Geographic for the Goldman Environmental Prize, and one of seven recipients this year, he will reopen the clinic, closed in 1998 for lack of funds, with part of the $125,000 award.



LYNN JOHNSON

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Brief Summary of Prescribing Information

CONTRAINDICATIONS: Active liver disease or unexplained persistent elevations of serum transaminases. Hypersensitivity to any component of this medication. **Pregnancy and Lactation** — Atherosclerosis is a chronic process and discontinuation of lipid-lowering drugs during pregnancy should have little impact on the outcome of long-term therapy of primary hypercholesterolemia. Cholesterol and other products of cholesterol biosynthesis are essential components for fetal development (including synthesis of steroids and cell membranes). Since HMG-CoA reductase inhibitors decrease cholesterol synthesis and possibly the synthesis of other biologically active substances derived from cholesterol, they may cause fetal harm when administered to pregnant women. Therefore, HMG-CoA reductase inhibitors are contraindicated during pregnancy and in nursing mothers. ATORVASTATIN SHOULD BE ADMINISTERED TO WOMEN OF CHILDBEARING AGE ONLY WHEN SUCH PATIENTS ARE HIGHLY UNLIKELY TO CONCEIVE AND HAVE BEEN INFORMED OF THE POTENTIAL HAZARDS. If the patient becomes pregnant while taking this drug, therapy should be discontinued and the patient apprised of the potential hazard to the fetus.

WARNINGS: Liver Dysfunction — HMG-CoA reductase inhibitors, like some other lipid-lowering therapies, have been associated with biochemical abnormalities of liver function. **Persistent elevations (>3 times the upper limit of normal [ULN] occurring on 2 or more occasions) in serum transaminases occurred in 0.7% of patients who received atorvastatin in clinical trials. The incidence of these abnormalities was 0.2%, 0.2%, 0.6%, and 2.3% for 10, 20, 40, and 80 mg, respectively.** One patient in clinical trials developed jaundice. Increases in liver function tests (LFT) in other patients were not associated with jaundice or other clinical signs or symptoms. Upon dose reduction, drug interruption, or discontinuation, transaminase levels returned to or near pretreatment levels without sequelae. Eighteen of 30 patients with persistent LFT elevations continued treatment with a reduced dose of atorvastatin. **It is recommended that liver function tests be performed prior to and at 12 weeks following both the initiation of therapy and any elevation of dose, and periodically (eg, semiannually) thereafter.** Liver enzyme changes generally occur in the first 3 months of treatment with atorvastatin. Patients who develop increased transaminase levels should be monitored until the abnormalities resolve. Should an increase in ALT or AST of >3 times ULN persist, reduction of dose or withdrawal of atorvastatin is recommended. Atorvastatin should be used with caution in patients who consume substantial quantities of alcohol and/or have a history of liver disease. Active liver disease or unexplained persistent transaminase elevations are contraindications to the use of atorvastatin (see CONTRAINDICATIONS). **Skeletal Muscle — Rhabdomyolysis with acute renal failure secondary to myoglobinuria has been reported with other drugs in this class.** Uncomplicated myalgia has been reported in atorvastatin-treated patients (see ADVERSE REACTIONS). Myopathy, defined as muscle aches or muscle weakness in conjunction with increases in creatine phosphokinase (CPK) values >10 times ULN, should be considered in any patient with diffuse myalgias, muscle tenderness or weakness, and/or marked elevation of CPK. Patients should be advised to report promptly unexplained muscle pain, tenderness or weakness, particularly if accompanied by malaise or fever. Atorvastatin therapy should be discontinued if markedly elevated CPK levels occur or myopathy is diagnosed or suspected. The risk of myopathy during treatment with other drugs in this class is increased with concurrent administration of cyclosporine, fibric acid derivatives, erythromycin, niacin, or azole antifungals. Physicians considering combined therapy with atorvastatin and fibric acid derivatives, erythromycin, immunosuppressive drugs, azole antifungals, or lipid-lowering doses of niacin should carefully weigh the potential benefits and risks and should carefully monitor patients for any signs or symptoms of muscle pain, tenderness, or weakness, particularly during the initial months of therapy and during any periods of upward dosage titration of either drug. Periodic creatine phosphokinase (CPK) determinations may be considered in such situations, but there is no assurance that such monitoring will prevent the occurrence of severe myopathy. **Atorvastatin therapy should be temporarily withheld or discontinued in any patient with an acute, serious condition suggestive of a myopathy or having a risk factor predisposing to the development of renal failure secondary to rhabdomyolysis (eg, severe acute infection, hypotension, major surgery, trauma, severe metabolic, endocrine and electrolyte disorders, and uncontrolled seizures).**

PRECAUTIONS: General — Before instituting therapy with atorvastatin, an attempt should be made to control hypercholesterolemia with appropriate diet, exercise, and weight reduction in obese patients, and to treat other underlying medical problems (see INDICATIONS AND USAGE in full prescribing information). **Information for Patients** — Patients should be advised to report promptly unexplained muscle pain, tenderness, or weakness, particularly if accompanied by malaise or fever. **Drug Interactions** — The risk of myopathy during treatment with other drugs of this class is increased with concurrent administration of cyclosporine, fibric acid derivatives, niacin (nicotinic acid), erythromycin, azole antifungals (see WARNINGS, Skeletal Muscle). ***Antacid:*** When atorvastatin and Maalox® TC suspension were coadministered, plasma concentrations of atorvastatin decreased approximately 35%. However, LDL-C reduction was not altered. ***Antipyrine:*** Because atorvastatin does not affect the pharmacokinetics of antipyrine, interactions with other drugs metabolized via the same cytochrome isozymes are not expected. ***Colestipol:*** Plasma concentrations of atorvastatin decreased approximately 25% when colestipol and atorvastatin were coadministered. However, LDL-C reduction was greater when atorvastatin and colestipol were coadministered than when either drug was given alone. ***Cimetidine:*** Atorvastatin plasma concentrations and LDL-C reduction were not altered by coadministration of cimetidine. ***Digoxin:*** When multiple doses of atorvastatin and digoxin were coadministered, steady-state plasma digoxin concentrations increased by approximately 20%. Patients taking digoxin should be monitored appropriately. ***Erythromycin:*** In healthy individuals, plasma concentrations of atorvastatin increased approximately 40% with coadministration of atorvastatin and erythromycin, a known inhibitor of cytochrome P450 3A4 (see WARNINGS, Skeletal Muscle). ***Oral Contraceptives:*** Coadministration of atorvastatin and an oral contraceptive increased AUC values for norethindrone and ethinyl estradiol by approximately 30% and 20%. These increases should be considered when selecting an oral contraceptive for a woman taking atorvastatin. ***Warfarin:*** Atorvastatin had no clinically significant effect on prothrombin time when administered to patients receiving chronic warfarin treatment. **Endocrine Function** — HMG-CoA reductase inhibitors interfere with cholesterol synthesis and theoretically might blunt adrenal and/or gonadal steroid production. Clinical studies have shown that atorvastatin does not reduce basal plasma cortisol concentration or impair adrenal reserve. The effects of HMG-CoA reductase inhibitors on male fertility have not been studied in adequate numbers of patients. The effects, if any, on the pituitary-gonadal axis in premenopausal women are unknown. Caution should be exercised if an HMG-CoA reductase inhibitor is administered concomitantly with drugs that may decrease the levels or activity of endogenous steroid hormones, such as ketoconazole, spironolactone, and cimetidine. **CNS Toxicity** — Brain hemorrhage was seen in a female dog treated for 3 months at 120 mg/kg/day. Brain hemorrhage and optic nerve vacuolation were seen in another female dog that was sacrificed in moribund condition after 11 weeks of escalating doses up to 280 mg/kg/day. The 120 mg/kg dose resulted in a systemic exposure approximately 16 times the human plasma area-under-the-curve (AUC, 0-24 hours) based on the maximum human dose of 80 mg/day. A single tonic convulsion was seen in each of 2 male dogs (one treated at 10 mg/kg/day and one at 120 mg/kg/day) in a 2-year study. No CNS lesions have been observed in mice after chronic treatment for up to 2 years at doses up to 400 mg/kg/day or in rats at doses up to 100 mg/kg/day. These doses were 6 to 11 times (mouse) and 8 to 16 times (rat) the human AUC (0-24) based on the maximum recommended human dose of 80 mg/day. CNS vascular lesions, characterized by perivascular hemorrhages, edema, and mononuclear cell infiltration of perivascular spaces, have been observed in dogs treated with other members of this class. A chemically similar drug in this class produced optic nerve degeneration (Wallerian degeneration of retinogeniculate fibers) in clinically normal dogs in a dose-dependent fashion at a dose that produced plasma drug levels about 30 times higher than the mean drug level in humans taking the highest recommended dose. **Carcinogenesis, Mutagenesis, Impairment of Fertility** — In a 2-year carcinogenicity study in rats at dose levels of 10, 30, and 100 mg/kg/day, 2 rare tumors were found in muscle in high-dose females: in one, there was a rhabdomyosarcoma and, in another, there was a fibrosarcoma. This dose represents a plasma AUC (0-24) value of approximately 16 times the mean human plasma drug exposure after an 80 mg oral dose. A 2-year carcinogenicity study in mice given 100, 200, or 400 mg/kg/day resulted in a significant increase in liver adenomas in high-dose males and liver carcinomas in high-dose females. These findings occurred at plasma AUC (0-24) values of approximately 6 times the mean human plasma drug exposure after an 80 mg oral dose. *In vitro*, atorvastatin was not mutagenic or clastogenic in the following tests with and without metabolic activation: the Ames test with *Salmonella typhimurium* and *Escherichia coli*, the HGPRT forward mutation assay in Chinese hamster lung cells, and the chromosomal aberration assay in Chinese hamster lung cells. Atorvastatin was negative in the *in vivo* mouse micronucleus test. Studies in rats performed at doses up to 175 mg/kg (15 times the human exposure) produced no changes in fertility. There was aplasia and aspermia in the epididymis of 2 of 10 rats treated with 100 mg/kg/day of atorvastatin for 3 months (16 times the human AUC at the 80 mg dose); testis weights were significantly lower at 30 and 100 mg/kg and epididymal weight was lower at 100 mg/kg. Male rats given 100 mg/kg/day for 11 weeks prior to mating had decreased sperm motility, spermatid head concentration, and increased abnormal sperm. Atorvastatin caused no adverse effects on semen parameters, or reproductive organ histopathology in dogs given doses of 10, 40, or 120 mg/kg for two years. **Pregnancy — Pregnancy Category X: See CONTRAINDICATIONS.** Safety in pregnant women has not been established. Atorvastatin crosses the rat placenta and reaches a level in fetal liver equivalent to that of maternal plasma. Atorvastatin was not teratogenic in rats at doses up to 300 mg/kg/day or in rabbits at doses up to 100 mg/kg/day. These doses resulted in multiples of about 30 times (rat) or 20 times (rabbit) the human exposure based on surface area (mg/m^2). In a study in rats given 20, 100, or 225 mg/kg/day, from gestation day 7 through to lactation day 21 (weaning), there was decreased pup survival at birth, neonate, weaning, and maturity in pups of mothers dosed with 225 mg/kg/day. Body weight was decreased on days 4 and 21 in pups of mothers dosed at 100 mg/kg/day; pup body weight was decreased at birth and at days 4, 21, and 91 at 225 mg/kg/day. Pup development was delayed (rotorod performance at 100 mg/kg/day and acoustic startle at 225 mg/kg/day; pinnae detachment and eye opening at 225 mg/kg/day). These doses correspond to 6 times (100 mg/kg) and 22 times (225 mg/kg) the human AUC at 80 mg/day. Rare reports of congenital anomalies have been received following intrauterine exposure to HMG-CoA reductase inhibitors. There has been one report of severe congenital bony deformity, tracheo-esophageal fistula, and anal atresia (VATER association) in a baby born to a woman who took lovastatin with dextroamphetamine sulfate during the first trimester of pregnancy. LIPITOR should be administered to women of child-bearing potential only when such patients are highly unlikely to conceive and have been informed of the potential hazards. If the woman becomes pregnant while taking LIPITOR, it should be discontinued and the patient advised again as to the potential hazards to the fetus. **Nursing Mothers** — Nursing rat pups had plasma and liver drug levels of 50% and 40%, respectively, of that in their mother's milk. Because of the potential for adverse reactions in nursing infants, women taking LIPITOR should not breast-feed (see CONTRAINDICATIONS). **Pediatric Use** — Treatment experience in a pediatric population is limited to doses of LIPITOR up to 80 mg/day for 1 year in 8 patients with homozygous FH. No clinical or biochemical abnormalities were reported in these patients. None of these patients was below 9 years of age. **Geriatric Use** — Treatment experience in adults age ≥70 years with doses of LIPITOR up to 80 mg/day has been evaluated in 221 patients. The safety and efficacy of LIPITOR in this population were similar to those of patients <70 years of age.

ADVERSE REACTIONS: LIPITOR is generally well-tolerated. Adverse reactions have usually been mild and transient. In controlled clinical studies of 2502 patients, <2% of patients were discontinued due to adverse experiences attributable to atorvastatin. The most frequent adverse events thought to be related to atorvastatin were constipation, flatulence, dyspepsia, and abdominal pain. **Clinical Adverse Experiences** — Adverse experiences reported in ≥2% of patients in placebo-controlled clinical studies of atorvastatin, regardless of causality assessment, are shown in the following table.

Adverse Events in Placebo-Controlled Studies (% of Patients)

BODY SYSTEM Adverse Event	Placebo N = 270	Atorvastatin 10 mg N = 863	Atorvastatin 20 mg N = 36	Atorvastatin 40 mg N = 79	Atorvastatin 80 mg N = 94
BODY AS A WHOLE					
Infection	10.0	10.3	2.8	10.1	7.4
Headache	7.0	5.4	16.7	2.5	6.4
Accidental Injury	3.7	4.2	0.0	1.3	3.2
Flu Syndrome	1.9	2.2	0.0	2.5	3.2
Abdominal Pain	0.7	2.8	0.0	3.8	2.1
Back Pain	3.0	2.8	0.0	3.8	1.1
Allergic Reaction	2.6	0.9	2.8	1.3	0.0
Asthenia	1.9	2.2	0.0	3.8	0.0
DIGESTIVE SYSTEM					
Constipation	1.8	2.1	0.0	2.5	1.1
Diarrhea	1.5	2.7	0.0	3.8	5.3
Dyspepsia	4.1	2.3	2.8	1.3	2.1
Flatulence	3.3	2.1	2.8	1.3	1.1
RESPIRATORY SYSTEM					
Sinusitis	2.6	2.8	0.0	2.5	6.4
Pharyngitis	1.5	2.5	0.0	1.3	2.1
SKIN AND APPENDAGES					
Rash	0.7	3.9	2.8	3.8	1.1
MUSCULOSKELETAL SYSTEM					
Arthralgia	1.5	2.0	0.0	5.1	0.0
Myalgia	1.1	3.2	5.6	1.3	0.0

The following adverse events were reported, regardless of causality assessment in patients treated with atorvastatin in clinical trials. The events in italics occurred in ≥2% of patients and the events in plain type occurred in <2% of patients.

Body as a Whole: *Chest pain*, face edema, fever, neck rigidity, malaise, photosensitivity reaction, generalized edema. ***Digestive System:*** *Nausea*, gastroenteritis, liver function tests abnormal, colitis, vomiting, gastritis, dry mouth, rectal hemorrhage, esophagitis, eructation, glossitis, mouth ulceration, anorexia, increased appetite, stomatitis, biliary pain, cheilitis, duodenal ulcer, dysphagia, enteritis, melena, gum hemorrhage, stomach ulcer, tenesmus, ulcerative stomatitis, hepatitis, pancreatitis, cholestatic jaundice. ***Respiratory System:*** *Bronchitis, rhinitis*, pneumonia, dyspnea, asthma, epistaxis. ***Nervous System:*** *Insomnia, dizziness*, paresthesia, somnolence, amnesia, abnormal dreams, libido decreased, emotional lability, incoordination, peripheral neuropathy, torticollis, facial paralysis, hyperkinesia, depression, hypesthesia, hypertonia. ***Musculoskeletal System:*** *Arthritis*, leg cramps, bursitis, tenosynovitis, myasthenia, tendinous contracture, myositis. ***Skin and Appendages:*** Pruritus, contact dermatitis, alopecia, dry skin, sweating, acne, urticaria, eczema, seborrhea, skin ulcer. ***Urogenital System:*** *Urinary tract infection*, urinary frequency, cystitis, hematuria, impotence, dysuria, kidney calculus, nocturia, epididymitis, fibrocystic breast, vaginal hemorrhage, albuminuria, breast enlargement, metrorrhagia, nephritis, urinary incontinence, urinary retention, urinary urgency, abnormal ejaculation, uterine hemorrhage. ***Special Senses:*** Amblyopia, tinnitus, dry eyes, refraction disorder, eye hemorrhage, deafness, glaucoma, parosmia, taste loss, taste perversion. ***Cardiovascular System:*** Palpitation, vasodilatation, syncope, migraine, postural hypotension, phlebitis, arrhythmia, angina pectoris, hypertension. ***Metabolic and Nutritional Disorders:*** *Peripheral edema*, hyperglycemia, creatine phosphokinase increased, gout, weight gain, hypoglycemia. ***Hemic and Lymphatic System:*** Ecchymosis, anemia, lymphadenopathy, thrombocytopenia, petechia. ***Postintroduction Reports*** — Adverse events associated with LIPITOR therapy reported since market introduction, that are not listed above, regardless of causality assessment, include the following: anaphylaxis, angioneurotic edema, bullous rashes (including erythema multiforme, Stevens-Johnson syndrome, and toxic epidermal necrolysis), and rhabdomyolysis.

OVERDOSAGE: There is no specific treatment for atorvastatin overdosage. In the event of an overdose, the patient should be treated symptomatically, and supportive measures instituted as required. Due to extensive drug binding to plasma proteins, hemodialysis is not expected to significantly enhance atorvastatin clearance.

Consult package insert before prescribing LIPITOR® (Atorvastatin Calcium) Tablets.

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MICHAEL AND PATRICIA FOGDEN/CORBIS

Bat Man

To capture in-your-face footage of bats for the National Geographic EXPLORER film *Vampire Bats*, airing October 29, producer Kevin Krug placed a small video camera, and himself, inside a hollow tree trunk in northwestern Nicaragua. "It was creepy," he says, "but we got the shot." Hear Krug's field tales—with video—at *nationalgeographic.com/fieldtales/bats*.

Women Photographers

The personal became professional when Karen Kasmauski, whose mother is from Yokosuka, shot a story on Japanese women: "I could explore my roots." Her work appears in our book *Women Photographers*. Find a preview portfolio and interviews at *. . . /photography/women*.



KAREN KASMAUSKI



Weather Sites

Need a forecast for a vacation spot, a map of hurricanes, or other weather data? Try the Web links at *. . . /info central/web/weather.htm*.

IMAGE PROCESSING BY MARIT JENTOFT-NILSEN AND FRITZ HASLER, GODDARD SPACE FLIGHT CENTER, NASA

My 24k Days. Go >

Birthday gift and card for my nephew. Earned 1,000 pts.





5th trip to Canada. Another great Radisson stay. Earned 7,500 pts.



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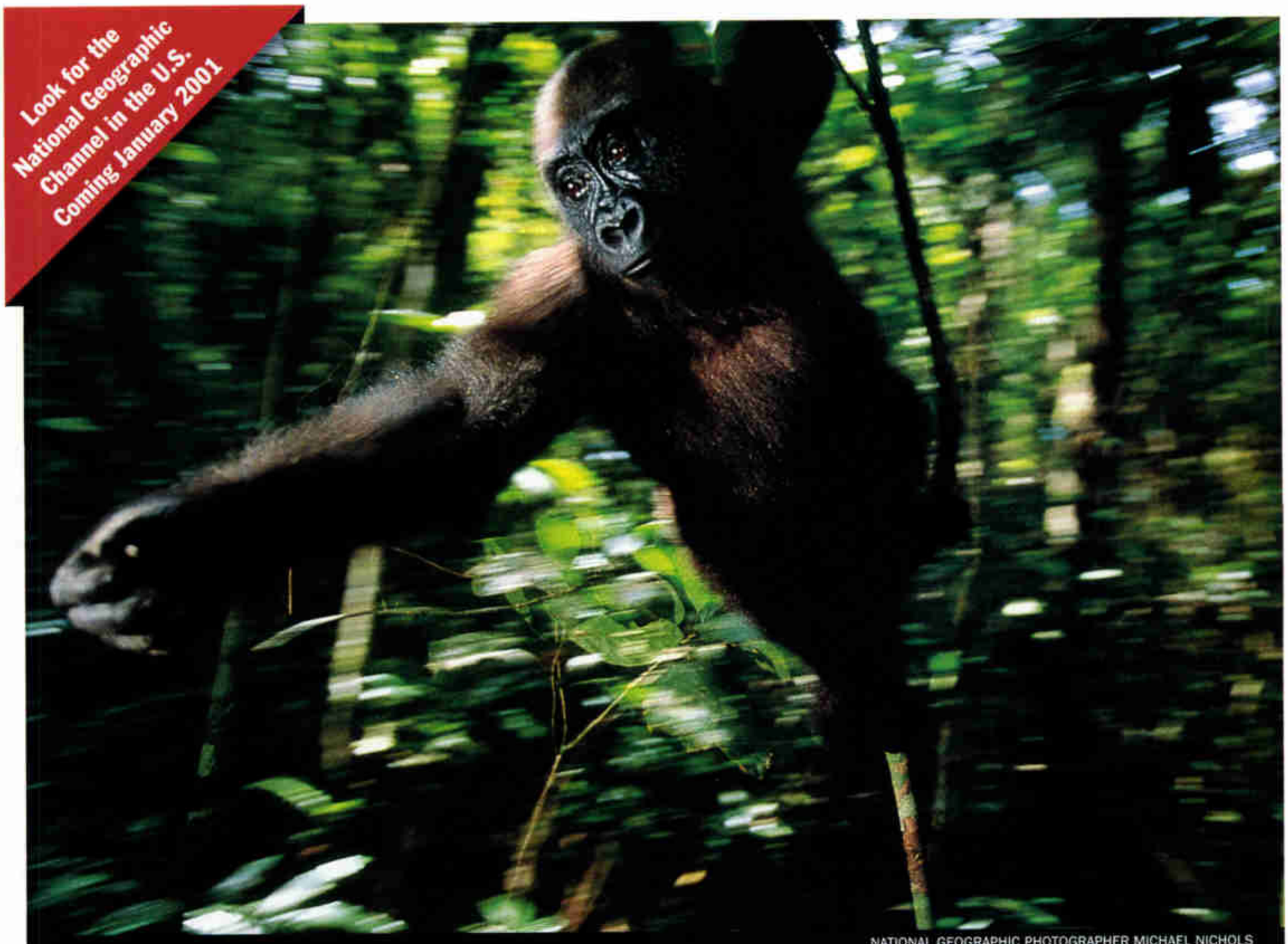
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NATIONAL GEOGRAPHIC PHOTOGRAPHER MICHAEL NICHOLS

EXPLORER, OCTOBER 1

Living in Harmony With Apes

Local people enlisted to help save primates

The first up-close study of western lowland gorillas in the wild reveals the natural behavior of creatures so far seen almost exclusively in zoos. The EXPLORER film *Living With Gorillas* follows Spanish primatologist Magdalena Bermejo and her husband, Germán Illera, as they conduct research in a densely forested region of the Republic of the Congo. In the tradition of Dian Fossey and Jane Goodall, Bermejo is seeking to habituate the gorillas to human presence in order to study them in their natural environment. Proponents say habituation will also promote ecotourism, giving local people an economic incentive to protect the primates. Bermejo focuses on a 350-pound male called Apollo and his 18-member family. The experience emboldened tracker Zepherin Okoko: "I'm no longer afraid of the gorillas. When I follow them all day, I learn to understand them."

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Ask Us

THE ANSWER PLACE

Our Research Correspondence staff responds to questions from curious readers.

Q Do fish ever go over Niagara Falls?

A Yes. Although most fish survive the plunge, it usually stuns them, making them easy prey for the gulls that hover at the base of the falls. Several years ago a falling salmon struck a tourist who was walking along a boardwalk below the 182-foot American Falls. Uninjured, the tourist took the fish home.

Q How far can you see across a body of water?

A On a clear day at sea level you can see about three miles to the horizon. The Earth curves out of view beyond that point. From an elevation of one mile you can see 98 miles. Hazy conditions and humidity lessen the viewing distance.

CARTOGRAPHIC

Q If Everest is Earth's highest mountain in relation to sea level, which is highest from its base?

A Rising nearly 32,000 feet from the Pacific Ocean floor, Hawaii's Mauna Kea volcano is the highest.



Q What area of the contiguous U.S. has the highest annual rainfall?

A According to the National Climatic Data Center, the wettest spot is 20 miles northnortheast of Aberdeen on Washington's Olympic Peninsula, with an average of 133 inches of rain a year.

Q What is the life expectancy of a mosquito?

A Once they leave the pupal stage of development, male mosquitoes typically live 7 to 10 days; females live as long as 30 days. The world's 3,000 species of mosquitoes are thought to transmit more diseases than any other creature.

MORE INFORMATION

Send questions to **Ask Us, National Geographic Magazine, PO Box 96095, Washington, DC 20090-6095** or via the Internet to **ngsaskus@nationalgeographic.com**. Include name, address, and daytime phone number.



TELL US

What are the spots strewn across this cobbled surface?

Think you know the answer? Go online to nationalgeographic.com/ngm/tellus/0010 and test yourself, or read it here in next month's issue.

SEPTEMBER ANSWER Hands never touch the hair of a Huli bachelor. He uses leafy twigs to drip sanctified water on his hair as it grows into a mushroom shape around bamboo supports. Soon it will be sheared off in one piece to make a wig he'll wear the rest of his life.

JOSÉ AZEL, AURORA (ABOVE); ROBERT MADDEN, NGS

BY DAVID QUAMMEN



MEGATR

ACROSS 1,200 MILES

At 11:22 on the morning of September 20, 1999, J. Michael

PHOTOGRAPHS BY MICHAEL NICHOLS

NATIONAL GEOGRAPHIC PHOTOGRAPHER



ANSECT

OF UNTAMED AFRICA ON FOOT

Fay strode away from a small outpost and into the forest in ▸

Plunging into the wild for science, J. Michael Fay of the Wildlife Conservation Society, at right, leads his survey party of Bambendjellé Pygmies through the Goualougo swamp of central Africa during his yearlong trek across the heart of the continent. His goal: to chronicle the region's still pristine forests. This is the first of three articles about the grueling journey.



a remote northern zone of the Republic of the Congo, setting

SCOUTING THE TERRITORY

off on a long and peculiarly ambitious hike. By his side was ▸

Born aloft, Fay's idea for the Megatransect was inspired by years of flying over central Africa, conducting aerial surveys of elephants. Such flights later helped him devise a route far from human encroachment. At the grass landing strip Fay used outside Kabo, local Pygmies (inset) named his plane Ngolio, *or great crowned eagle.*

an aging Pygmy named Ndokanda, a companion to Fay from

SCARRED BUT NOT AFRAID



adventures past, armed now with a new machete and ▸

An old friend, Ebobo is a solitary male that Fay first met seven years ago, when the gorilla was terrorizing a village. Fay and his colleagues talked the villagers out of killing Ebobo, then befriended the animal, which shows little fear of humans despite what appears to be a machete scar on his face. On a recent ramble in the bush (inset), he even waited for Fay to catch up.

On bush-hardened feet, *Fay follows the "path of least resistance" through the forest, using topographic maps as a rough guide. Along the way he notes "every pile of dung, every tree, every cry of a chimpanzee," with tools ranging from pencil and paper to a video recorder. Yet his purpose goes beyond the mere gathering of data: "I want people to feel the magic of walking on an elephant highway through groves of ancient trees."*





dubiously blessed with the honor of cutting trail. Nine other Pygmies marched after them, carrying waterproof bags of gear and food. Interspersed among that troop came still

other folk—a camp boss and cook, various assistants, Michael "Nick" Nichols with his cameras, and me.

It was a hectic departure to what would eventually, weeks and months later, seem a quiet, solitary journey. Fay planned to walk across central Africa, more than a thousand miles, on a carefully chosen route through untamed regions of tropical forest and swamp, from northeastern Congo to the coast of Gabon. It would take him at least a year. He would receive resupply drops along the way, communicate as needed by satellite phone, and rest when necessary, but his plan was to stay *out there* the whole time, covering the full route in a single uninterrupted push. He would cross a northern stretch of the Congo River Basin, then top a divide and descend another major drainage, the Ogooué.

Any big enterprise needs a name, and Fay had chosen to call his the Megatransect—*transect* as in cutting a line, *mega* as in mega, a label that variously struck those in the know as amusing or (because survey transects in field biology are generally straight and involve statistically rigorous repetition) inappropriate. Fay is no sobersides, but amusement was not his intent. Behind this mad lark lay a serious purpose—to observe, to count, to measure, and from those observations and numbers to construct a portrait of great central African forests before their greatness succumbs to the inexorable nibble of humanity. The measuring began now. One of Fay's entourage, a bright young Congolese named Yves Constant Madzou, paused at the trailhead to tie the loose end of a string to a small tree.

I paused beside him, intrigued. In the technical lingo this string was known as a topofil. Its other end was wound on a conical spool inside a Fieldranger 6500, a device used by foresters for measuring distance along any walked route. The topofil pays out behind a walker while the machine counts traversed footage, much as a car's odometer counts miles. Each spool holds a six-kilometer (3.7-mile) length.

Behind this mad lark lay

Madzou carried a half dozen extras, and somewhere among the expedition supplies were many more. Having served its purpose each day, the string would quickly disappear down the gullets of termites and other jungle digesters, I'd been told, but the numbers it delivered with such Hansel and Gretel simplicity would be accurate to the nearest 12 inches. You can't get that precision from a global positioning system (GPS) and a map. Running the topofil was to be one of Madzou's assignments.

Now, as he stepped out after Fay in the first





minutes of Day 1, the Fieldranger gurgled in a low, wheezy tone. Madzou trailed filament like a spider. The string hovered, chest high, under tension. And I found it piquant to contemplate that if Fay's expedition proceeds to its fulfillment, a thousand-mile length of string will go furling out through the equatorial jungle.

That string seemed an emblem of all the oxymoronic combinations this enterprise embodies—high tech and low tech, vast scales and tiny ones, hardheaded calculation and loony daring, strength and fragility, glorious tropical wilderness and a mitigated smidgen of litter. As he walks, Fay will gather data in many dimensions by many means, including digital video camera, digital audio recorder, digital still camera, GPS, thermohygrometer (whatever that is), handheld computer, digital calipers, hand lens (for squinting at tiny specimens), and notebook and pencil. The topofil will be a quaint but important complement to the rest.

Within less than an hour on the first day we're shin-deep in mud, crossing the mucky perimeter of a creek. "Doesn't take long for the swamps to kick in around here," Fay says cheerily. He's wearing his usual outfit for a jungle hike: river sandals, river shorts, a lightweight synthetic T-shirt that can be rinsed out each evening and worn again next day, and the day after, and every day after that until it disintegrates. River sandals are preferable to running shoes or tall rubber boots, he has found, because the forest terrain of northeastern Congo is flat and sumpy, its patches of solid ground interlaced with leaf-clotted spring seeps and black-water creeks, each of them guarded by a corona of swamp. A determined traveler on a compass-line march is often obliged to wallow through sucking gumbo, cross a waist-deep channel of whiskey-dark water flowing gently over a bottom of white sand, wallow out through the muck zone on the far side, rinse off, and keep walking. Less determined travelers, in their Wellingtons and bush pants, just don't get to the places where Fay goes.

He stops to enter a datum into his yellow "Rite in the Rain" notebook: elephant dung, fresh. Blue-and-black swallowtail butterflies flash in sun shafts that penetrate the canopy. He notes some fallen fruits of the plant *Vitex grandifolia*. Trained as a botanist before he shifted focus to do his doctorate on west-

a serious purpose . . . a portrait of great central African forests.

ern lowland gorillas, Fay's command of the botanical diversity upon which big mammals depend is impressive—he seems familiar with every tree, vine, and herb. He knows the feeding habits of the forest elephant (*Loxodonta africana cyclotis*, the smaller subspecies of African elephant adapted to the woods and soggy clearings of the Congo Basin) and the life cycles of the plants that produce the fruits it prefers. He can recognize, from stringy fecal evidence, when a chimpanzee has been eating a certain latex-rich fruit. He can identify an ambiguous tree by the smell of its inner bark. He

To recruit his team, *Fay went to Makao, a Motaba River village frequented by Bambendjellé living as they have for thousands of years—in a world ruled by forest spirits such as Ekambo Deki (below right), a hunting deity "captured" at a forest camp and made to dance. Among the men Fay hired was Mambeleme (below, holding his child), who became Fay's friend and right-hand man. "Mambeleme is hard as nails," marvels Fay, "yet as gentle as they come."*



sees the forest in its particulars and its connectedness. Now he bends pensively over a glob of civet dung. Then he makes another notation.

"Mmm. This is gonna be fun," he says, and walks on.

MIKE FAY ISN'T THE FIRST half-crazed white man to set out trekking across the Congo Basin. In a tradition that includes such Victorian-era explorers as David Livingstone, Verney Lovett Cameron, Savorgnan de Brazza, and Henry Morton Stanley, he's merely the latest. Like Stanley and some of the others, he has a certain gift for command, a level of personal force and psychological savvy that allows him to push a squad of men forward through difficult circumstances, using a mix of inspirational goading, promised payment, sarcasm, imperiousness, threat, tactical sulking, and strong example.

He's a paradoxical fellow and therefore hard to ignore, a postmodern redneck who chews Red Man tobacco, disdains political correctness, knows a bit about tractor repair and a lot about software, and views the suburbanized landscape of modern America with cold loathing. Born in New Jersey, raised there and in Pasadena, California, he has fully transplanted his sense of what's home. "I plan on dying out here," he says of the central African forest. "I'll never go back to live in the U.S."

What makes Fay different from those legendary Victorian zealots is that he's not traveling in service of God or empire or for the personal enrichment of the king of Belgium. He does have backers, most notably the Wildlife Conservation Society (WCS) of New York, for which he's a staff member on field assignment, and the National Geographic Society, but he's certainly not laboring for the greater glory of them. His driving motive—or rather

There are dire diseases, armed



the first and more public of his *two* driving motives—is conservation.

His immediate goal is to collect a huge body of diverse but intermeshed information about the biological richness of the ecosystems he'll walk through and about the degree of human presence and human impact. He'll gather field notes on the abundance of elephant dung, leopard tracks, chimpanzee nests, and magisterial old-growth trees. He'll make recordings of birdsong for later identification by experts. He'll store away precise longitude-latitude readings (automatically, every 20 seconds throughout the walking day) with his Garmin GPS unit and the antenna duct-taped into his hat. He'll detect gorillas by smell and by the stems of freshly chewed *Haumania danckelmaniana*, a tangly monocot plant they munch like celery. Eventually he will systematize those data into an informational resource unlike any ever before assembled on such a scale—with the ultimate goal of seeing that resource used wisely by the managers and the politicians who will decide the fate of African landscapes.

"It's not a scientific endeavor, this project," Fay acknowledges during one of our talks before departure. Nor is it a publicity stunt, he argues, answering an accusation that's been raised. What he means to do, he explains, is to "quantify a stroll through the woods."

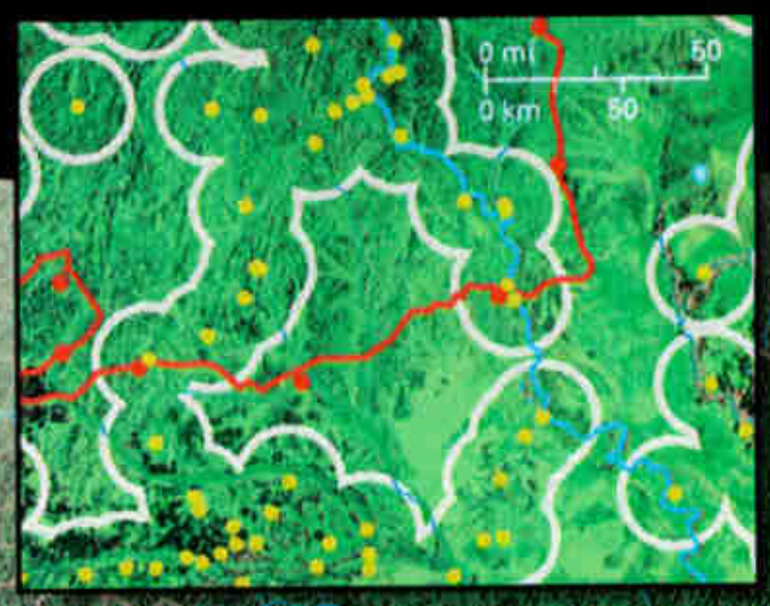
poachers, political disruptions, and other sorts of threat.



A JOINT PROJECT OF THE WILDLIFE CONSERVATION SOCIETY AND THE NATIONAL GEOGRAPHIC SOCIETY

EXTREME AFRICA

A massive undertaking that took years to plan, Michael Fay's journey makes a scientific transect, or survey pass, through some of the richest and least explored ecosystems on Earth. The carefully chosen route threads through the heart of 13 connected forests (green labels) that together constitute a wilderness the size of Florida—the largest expanse of wild land remaining in central Africa. Beginning at Bomassa, Congo, the team surveyed national parks as well as unprotected forests crisscrossed by logging roads. Their ultimate destination: the coast of Gabon.





J. MICHAEL FAY



Minkebé forest

GABON

Ogooué

Mingouli forest

Lopé National Park

Lopé forest

Abeilles forest

Iboundji-Fougoumou

Western Gamba complex

Doudou Mountains

Moukalaba forest

ATLANTIC OCEAN

MAP KEY
- Route traveled
- Proposed route
- Supply stop
- Road
- Trail
- Railroad
- Park
- Forest area

0 mi 50
0 km 50

NATIONAL GEOGRAPHIC MAPS

To encounter wildlife in its natural state, Fay designed the route of his Megatransect to skirt towns and villages (yellow dots, left) by as wide a margin as possible, although he occasionally passes through one to survey its impact on surrounding wildlife populations. His reconnaissance flights also revealed biological hot spots such as this forest clearing, or *bai* (left), with a single elephant on its left bank.

CENTRAL AFRICAN REPUBLIC

CAMEROON

C O N G O

START Sept. 20, 1999

Fay's location as of Feb. 15, 2000

Likboyo savanna

NOUABALÉ-NDOKI N.P.

Makao

Noudbalé R.

Motaba

Oubangui

Mopo River

Mbeli Bai

Goualougo River

Bomassa

Goualougo Triangle

Nouabalé-Ndoki

Kabo

Ndoki River

Likouala aux Herbes swamp

Ndoki II (camp)

Ouesso

Djoua Valley

ODZALA NATIONAL PARK

Pokola

Lac Télé

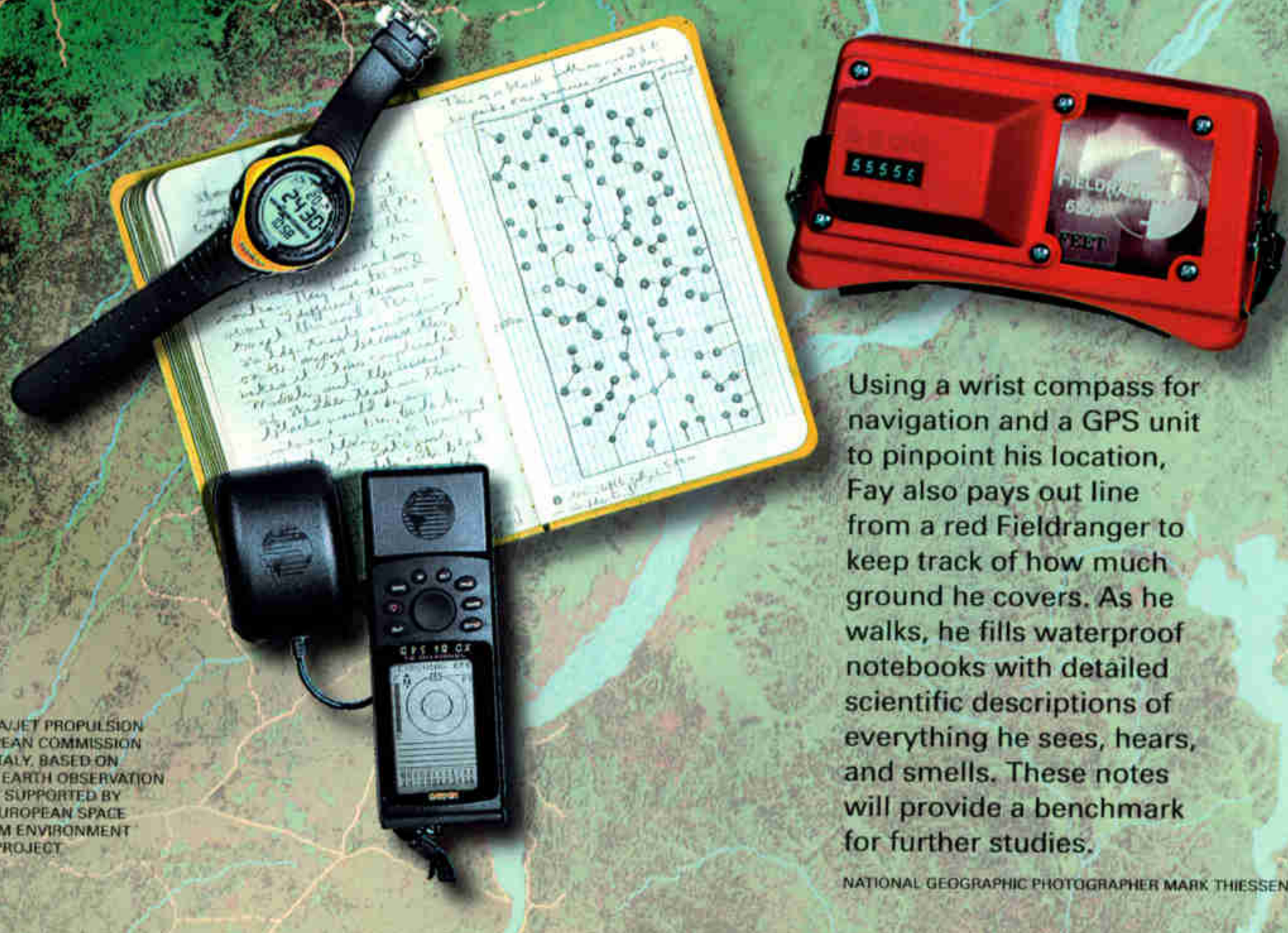
Odzala

Lengoue

Southern Pokola

Sangha

Congo



Using a wrist compass for navigation and a GPS unit to pinpoint his location, Fay also pays out line from a red Fieldranger to keep track of how much ground he covers. As he walks, he fills waterproof notebooks with detailed scientific descriptions of everything he sees, hears, and smells. These notes will provide a benchmark for further studies.

NATIONAL GEOGRAPHIC PHOTOGRAPHER MARK THIESSEN

LAND-COVER MOSAIC BY NASA/JET PROPULSION LABORATORY AND THE EUROPEAN COMMISSION JOINT RESEARCH CENTRE IN ITALY, BASED ON IMAGES FROM THE JAPANESE EARTH OBSERVATION SATELLITE-1. INTERPRETATION SUPPORTED BY NASA PATHFINDER AND THE EUROPEAN SPACE AGENCY TROPICAL ECOSYSTEM ENVIRONMENT MONITORING BY SATELLITES PROJECT





PUZZLING OVER THE PAST

A neat circle of clouds is reflected in the mirrorlike surface of Lac Télé in northern Congo, a 3.5-mile-wide basin surrounded by a vast swamp. Fifteen miles away Fay's overflights revealed raised terraces (above) suggesting past cultivation. Fay theorizes that in the recent past many more people lived and farmed this region, which may have been depopulated by the slave trade.

Then there's his second driving motive. He doesn't voice it explicitly, but I will: Mike Fay is an untamable man who just loves to walk in the wilds.

Completing this thousand-mile trek won't be easy, not even for him. There are dire diseases, armed poachers, political disruptions, and other sorts of threat and mishap that could stop him. He's familiar with malaria and filariasis, aware of Ebola, and has found himself inconveniently susceptible to foot worms, a form of parasite that can travel from elephant dung into exposed human feet, burrowing tunnels in a person's toes, only to die there and fester. But the biggest challenge for Fay will come *after* all his walking.

Can he make good on the claim that this encyclopedia of field data will be useful? Can he channel his personal odyssey into practical results for the conservation of African forests?

SUDDENLY, a mile and a quarter on, Fay makes a vehement hand signal: *stop*. As we stand immobile and hushed, a young male elephant appears, walking straight toward us through the understory. Ndokanda slides prudently to the back of the file, knowing well that a forest elephant, nearsighted and excitable, is far more dangerous than, say, a leopard. Fay raises the video camera. The elephant, visually oblivious and upwind of our smell, keeps coming. The videotape rolls quietly. When the animal is just 15 feet from him and barely twice that from the rest of us—too close for anyone's comfort—Fay says in a calm voice: "Hello." The elephant spooks, whirls around, disappears with its tail streaming high.

Tusk length, about 40 centimeters, Fay says. Maybe ten or twelve years old, he estimates. It goes into his notebook.



Fay is a compact 43-year-old American with a sharp chin and a lean, wobbly nose. Behind his wire-rimmed glasses, with their round, smoky lenses, he bears a disquieting resemblance to the young Roman Polanski. Say something that's doltish or disagreeable, and he'll gaze at you silently the way a heron, hungry or not, gazes at a fish. But on the trail he's good company, a man of humor and generous intellect. He sets a punishing pace, starting at daylight, never stopping for lunch or rest, but when there are field data to record in his yellow notebook, fortunately, he pauses often.

We leave camp just after dawn on Day 3 and follow the Mopo River downstream along a network of elephant trails. We're a smaller group now, Nick Nichols and his assistant having gone off to photograph some Bambendjellé Pygmy groups, intending to rendezvous with Fay several weeks later. Fay, Madzou, and I set out while the crew are still eating breakfast, giving us a relatively quiet first look at forest activity. Under a high canopy of *Gilbertiodendron dewevrei* trees, the walking is easy. The understory is sparse and well trampled by elephant traffic, as it generally tends to be in these dominant stands of *G. dewevrei*, more familiar to the Pygmies as *bemba.* Later, as we swing away from the river onto higher ground, the bemba gives way to a mixed forest, its canopy gaps delivering light to a clamorous undergrowth of brush, saplings, vines, thorny monocots, and woody lianas, through which we climb hunchbacked behind the day's point man. The thickest zones of such early successional vegetation are known in the local language as *kaka*, a coincidental but appropriate convergence with the scatological slang term from various other languages. Kaka to a Pygmy, "crappy forest" to you and me. Today it's Bakembe, younger and



After dark there comes a weird, violent, whooshing noise

stronger than Ndokanda, who cuts us a tunnel through the kaka.

The most devilish of the thorny plants is *Haumania danckelmaniana,* mentioned already as a favored gorilla food. Looping high and low throughout the understory, weaving the kaka into a tropical brier patch, forever finding chances to carve bloody scratches across unprotected ankles and toes, *H. danckelmaniana* is the bushwhacker's torment. Even a Congo walker as seasoned as Fay has to spend much of his time looking down, stepping carefully, minimizing the toll on his feet. Of course Fay would be looking down anyway, because that's where so much of the data are found—scat piles, footprints, territorial scrape marks, masticated stems, serpentine tracks left by red river hogs nose-plowing through leaf litter, pangolin burrows, aardvark burrows, fallen leaves, fallen fruit. Fay's GPS tells us where we are, while his map and our compasses tell us which way to go. We see no human trails in this forest, because there are no resident humans, few visitors, and no destinations.

Fay pauses over a pile of gorilla dung, recognizing seeds of *Maranthes glabra* as a hint about this animal's recent diet. Farther on he notes the hole where a salt-hungry elephant has dug for minerals. Farther still the print of a yellow-backed duiker, one of the larger forest antelope. Each datum goes into the notebook, referenced to the minute of the day, which will be referenced in turn by his GPS to longitude and latitude at three decimal points of precision. Years from now, his intricate database will be capable of placing that very pile of gorilla dung at its exact dot in space-time, should anyone want to know.

WHEN IT COMES time to ford the Mopo, Fay wades knee-deep into the channel with his video camera pressed to his face. Spotting a dark lump against the white sand, he gropes for it one-handed, still shooting. "*Voilà.* A palm nut." He shows me the hard, striated lump, smaller than a walnut, light in weight but heavy with import. It's probably quite old, he explains. He has found thousands like this in his years of wading the local rivers, and carbon-dating analysis of a sizable sample revealed them to be durable little subfossils, ranging in age between about 1,000 and 2,400 years. Presumably they wash into streams after centuries of shallow burial in the soil nearby. What makes their presence mysterious is that this species of palm, *Elaeis guineensis,* is known mainly as an agricultural species, grown on



Wise in the ways of the forest, *a Bambendjellé family (above) takes refuge from the rain under a shelter of sticks and leaves. Though not a true rain forest—Congo's annual rainfall totals less than a hundred inches—the forest is often flooded, allowing another family to set out on a fishing trip (left). In her hands the mother cradles a coal—the makings of a fire.*

that rises mystifyingly.

plantations near traditional Bantu villages at the fringe of the forest and harvested for its oil. *Elaeis guineensis* seems to need cleared land, or at least edges, and to be incapable of competing in dense, mature forest.

The abundance of ancient oil palm nuts in the river channels suggests a striking possibility: that a vast population of proto-Bantu agriculturalists once occupied this now vacant and forested region. So goes Fay's line of deduction anyway. He hypothesizes that they cut the forest, established palm plantations, discarded millions or billions of palm nuts in the process of extracting oil, and then vanished mysteriously. Some scholars argue that natural climate change over the past three millennia might account for the coming and going of oil palms, the natural ebb and return of forest, but to Fay it doesn't make sense, given the apparent dependence of *Elaeis guineensis* on human agriculturalists. "What makes sense," he says, "is that people moved in here, grew palm nuts, and then died out." Died out? From *what?* He can only guess: maybe warfare, or a killer drought, or population overshoot leading to ecological collapse. Or maybe an early version of AIDS or Ebola emptied the region of people, more or less abruptly, allowing the forest to regrow. There's no direct evidence for this cataclysmic depopulation, but it's a theme that will recur throughout Fay's hike. Meanwhile, he drops the palm nut into a Ziploc bag.

Beyond the Mopo we sneak up on a group of gorillas feeding placidly in a *bai,* a boggy clearing amid the forest. We approach within a hundred feet of an oblivious female as she works her way through a salad of *Hydrocharis* stems, nipping off the tender white bases, tossing the rest aside. Her face is long and tranquil, with dark eyes shaded beneath the protrusive brow. The hair on her head is red, Irish red, as it often is among adult lowland gorillas. Her arms are huge, her hands big and careful. Leaving me behind, Fay skulks closer along the bai's perimeter. When the female raises her head to look straight in his direction, the intensity of her stare seems to bring the whole forest to silence. For a minute or two she looks puzzled, wary, menacingly stern. Then she resumes eating. Fay gets the moment on zoom-lens video. Later he tells me that he froze every muscle

DANCING WITH DEATH

Life mocks death in the forest outside Makao, where a group of Bambendjellé dance in unison, demonstrating how to taunt a thieving spirit known as Enyomo, the bundled figure at right. A ritual sometimes used after a death and burial, this dance is one of dozens the Bambendjellé perform to commune with ever present forest spirits.





Hard traveling *takes its toll as the survey team fights off exhaustion and disease two months into the trek. Part doctor, part cheerleader, Fay treats one of his men (center) with penicillin for yaws, a skin disorder rampant among Pygmies in the Congo. Besides collecting data, Fay (far right) also carries the burden of "getting 15 souls safely across 1,200 miles of forest. One bad decision could mean disaster, death, or complete demoralization."*

during those seconds she glowered at him, not daring to lower the camera, not daring to move, while a tsetse fly sucked blood from his foot.

The video camera, with its sound track for verbal annotations and its date-and-time log, is becoming one of his favorite tools. He shoots footage of major trees, posing a Pygmy among the buttresses for scale. He shoots footage of monitor lizards and big unidentified spiders. He shoots footage, for the hell of it, of me floundering waist-deep in mud. Occasionally he does a slow 360-degree pan to show the wraparound texture of a patch of forest. And when I alert him that a leech has attached itself to one of the sores on his right ankle, he videos that. Then he hands me the camera, while Madzou burns the leech off with a lighter, so I can capture the operation from a better angle.

At noon he inspects another fresh mound of elephant dung, poking his finger through the mulchy gobs. Elephants here eat a lot of fallen fruit, but just what's on the menu lately? He picks out seeds of various shape and size, identifying each at a glance, reciting the Latin binomials as he tosses them into a pile: "*Panda oleosa, Tridesmostemon omphalocarpoides, Antrocaryon klaineanum, Duboscia macrocarpa, Tetrapleura tetraptera, Drypetes gossweileri,* and what's this other little thing, can't remember, wait, wait . . . oh yeah, *Treculia africana.*"

As I squat beside him, impressed by his knowledge and scribbling the names, he adds: "Of course, this is where you get foot worms, standing in elephant dung like this."

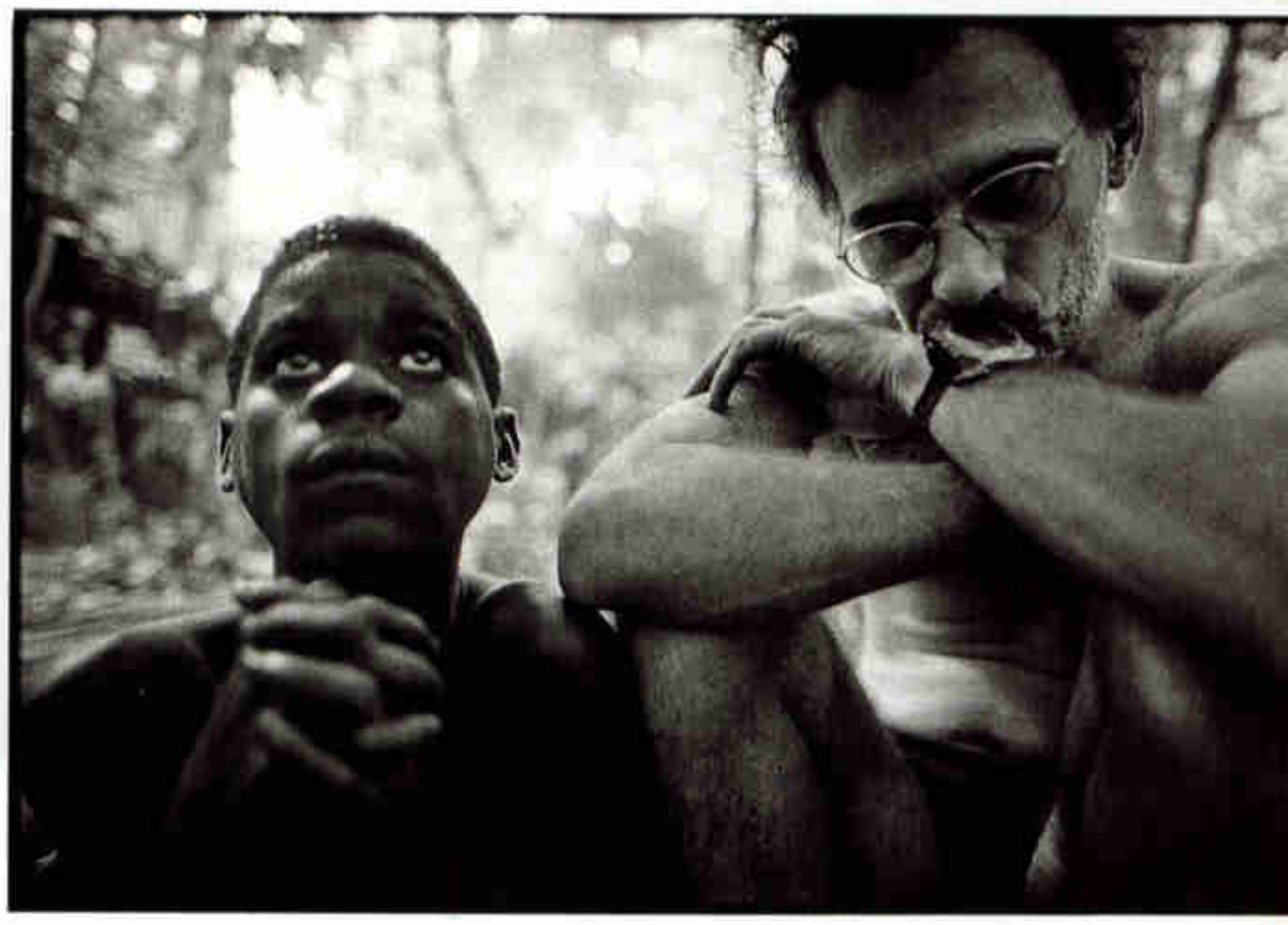
We make camp along a tributary of the Mopo. The Pygmies erect a roof beam for the main tarp and a log bench for our ease before the campfire. According to the topofil, Madzou reports, our day's progress has been 33,420 feet. Not a long walk, but a full one. After dark, as Fay and Madzou and I sit eating popcorn, there comes a weird, violent, whooshing noise that rises mystifyingly toward crescendo, and then crests—as, whoa, an elephant charges through camp, like a freight train with tusks. As the Pygmies dive for safety, sparks explode from the campfire as though someone had dropped in a Roman candle. Then, as quickly, the elephant is gone. Anybody hurt? No. Dinner is served and the pachyderm in the kitchen is forgotten, just a minor distraction at the end of a typical day on the Megatransect.

Fay spent the late 1980s at a site in the Central African Republic, doing fieldwork on lowland gorillas for his doctorate. One of the methods he used was the line-transect survey,

"Of course, this is where you

which involved cutting straight trails through his study area, a multiple array of them in parallel, and then walking the trails repeatedly to locate and count gorilla nests. Line transects are a familiar tool among field biologists, most often used to estimate total abundance of some species within a large area by statistical derivation from a small, relatively convenient sample. Another of Fay's field methods, which proved more congenial to his disposition, was what he labeled the "group follow." With a trusted Pygmy tracker, he would follow one group of gorillas discreetly but persistently for all of one





day or several, holding back at distance enough (several hundred yards) to leave them unaware of his presence. Such fastidious tracking allowed him to learn what they had been eating, how many nests they had built, and how to make deductions about group size, ages, gender, while minimizing the chance that he'd spook these very shy primates. Toward the end of his study he and his Pygmy mentor followed one group from dawn to dark for 12 days, resting and eating and walking in a shadowy rhythm with the gorillas. From a reading of his eventual dissertation, it seems the 12-day follow was a high point in his academic fieldwork.

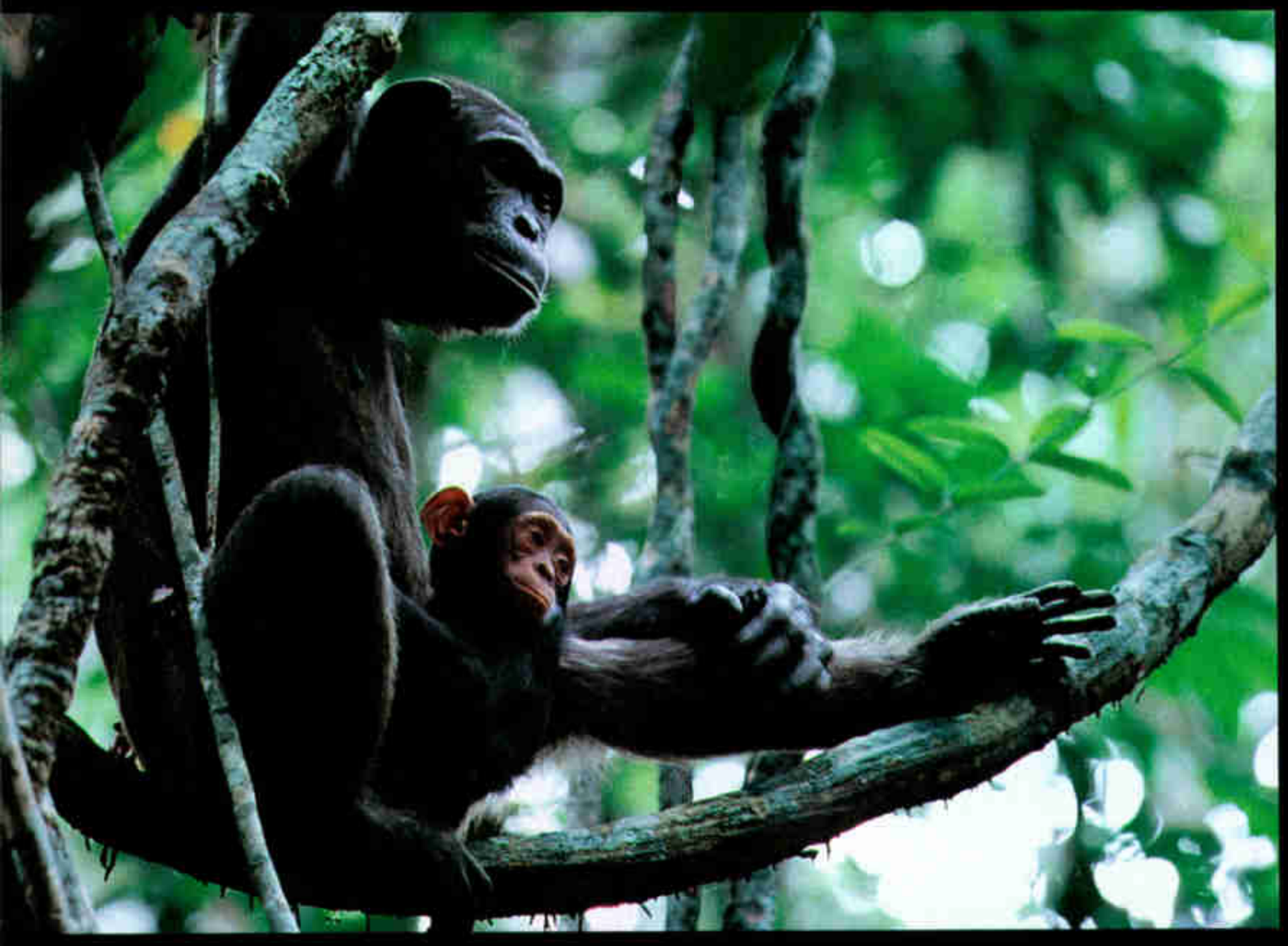
He returned to grad school in St. Louis meaning to write that dissertation, but after a few weeks he shoved it aside (not to be finished until eight years later) and flew back to Africa, seizing the irresistible distraction of more fieldwork. His new assignment was to do a survey of forest elephants in northern Congo. Fay was to focus the survey on three remote, difficult ecosystems: an area near the Gabonese border known as Odzala, a vast swampland to the east known as Likouala aux Herbes, and, farther north, a zone of trackless forest between the Nouabalé and Ndoki Rivers. Teaming up with an adventuresome Congolese biologist named Marcellin Agnagna, Fay set himself the delectable (to him) task of traversing all three areas on foot. A year later he returned for a second survey trek in the Nouabalé-Ndoki area, where he had found such a wonderland of unspoiled forest that it would eventually, after much determined but deft politicking by Fay and others, become one of Congo's most treasured national parks.*

By 1991 Fay himself was director of this Nouabalé-Ndoki National Park project, on a management contract between the Republic of the Congo government and the Wildlife Conservation Society. Although his administrative duties had grown heavy and his political reach had lengthened, he still slid out for a two- or three-week reconnaissance hike whenever the necessity or the excuse arose. And soon after that he began to brainstorm about applying his leg-power approach on a whole different scale.

On the afternoon of Day 5 we enter Nouabalé-Ndoki National Park, crossing the Ndoki River in dugout canoes borrowed from the park's little boat landing, then paddling up a deep black-water channel through meadows of swaying *Leersia* grass, and continuing onward by foot. We spend the last hour before sunset walking through a rainstorm so heavy it fills the trail with a cement-colored flood. On Day 7 we skirt the perimeter of Mbeli Bai, a large clearing much frequented by elephants and gorillas. His first glimpse of this bai back in 1990, Fay tells me, was an ugly experience: He found six elephant carcasses, some with their tusks already hacked out, others left to rot

get foot worms, standing in elephant dung like this."

*See "Ndoki—Last Place on Earth," by Douglas H. Chadwick, NATIONAL GEOGRAPHIC, July 1995.





FIRST CONTACT

Perhaps the last on Earth to have never seen a human, the chimpanzees of Goualougo Triangle showed no fear of Fay's team. "If we let this area be logged, we'll destroy our chance to know this animal in its natural state," says Fay. In the forest outside the village of Bomassa, by contrast, once wary elephants (right), protected here since 1991, are increasingly trusting of humans.

until the extraction would be easier. The park hadn't yet been decreed, and poaching was rampant. In recent years the situation has much improved.

The park has also brought protection to giant trees of the species most valued for timber, such as *Entandrophragma cylindricum,* informally known as sapele, one of the premium African hardwoods. Pointing to a big sapele, he says, "There's something you wouldn't see on the other side of the river"—that is, west of the park, where selective logging has already combed away the most formidable trees. Later he notes a mighty specimen of *Pericopsis elata,* far more valuable even than sapele. A log of *P. elata* that size is like standing gold, Fay says, worth serious money coming out of the sawmill. Spotting another, he changes his metaphor: "If sapele is the bread and butter around here, *Pericopsis* is the caviar."

WE LINGER through midafternoon with a group of unwary chimpanzees that have gathered around us at close range—an eerie experience, given that most chimps throughout central Africa are terrified of humans, who commonly hunt them as food. These animals perch brashly in trees just above us, hooting and gabbling excitedly, sending down pungent but unmalicious showers of urine, scratching, cooing, ogling us with intense curiosity. One female holds an infant with an amber face and huge, backlit orange ears, neither mother nor baby showing any fear. A young chimp researcher named Dave Morgan, who has joined us for this leg of the hike, counts 11 individuals, including one with a distinctively notched left earlobe.

It's a mesmerizing encounter, for us and them, but after two hours with the chimps we



push on, then find ourselves running out of daylight long before we've reached a suitable campsite. None of us wants a night without water. We grope forward in the dark, wearing headlamps now, cutting and twisting through kaka, finally stumbling into a sumpy, uneven area beside a muddy trickle, and Fay declares that this will do. Early next morning we hear chimps again, calling near camp. With Morgan's help we realize that it's probably the group from yesterday, having tracked us and bedded nearby. Camp-following chimps? The sense of weird and unearthly comity only increases when, on Day 8, we cross into an area known as the Goualougo Triangle.

At 4:15 that morning I'm awake in my tent, preparing for the day's walk by duct-taping over the sores and raw spots on my toes, ankles, and heels. To travel the way Mike Fay travels is hard on the feet, even hard on *his* feet, not because of the distance he walks but because of where and how. After a week of crossing swamps and stream channels behind him, I'm long since converted to Fay's notion of the optimal trail outfit—river sandals, shorts, one T-shirt that can be rinsed and dried. But the problem of foot care remains, partly because of the unavoidable cuts, stubs, and slashes inflicted by those thorny *H. danckelmaniana* stems and other hazards, partly because the sandy mud of Congolese swamps has an effect like sandpaper socks, chafing the skin away wherever a sandal strap binds against the foot. So I've adopted the practice of painting my feet with iodine every morning and night and (at the suggestion of another tough Congo trekker, a colleague of Fay's named Steve Blake) using duct tape to cover the old sores and protect against new ones. The stuff holds amazingly well through a day of swamp

SUBSISTENCE HUNTING



To feed his family, this man set out from his home on the Motaba River with a shotgun and a shell or two; he returned with this mustached monkey, abundant in local forests. "You hear a lot these days about the bush-meat problem," says Fay. "Well, it isn't the little guys. It's professionals—the hunters who kill lots of animals to feed increasing numbers of people."



Can he channel his personal odyssey into practical results for the

slogging, and although peeling off the first batch isn't fun, removal becomes easier on later evenings when there's no more hair on your feet. Since I've got a small roll of supple green tape, as well as a larger roll of the traditional (but stiffer, less comfortable) silver, I even find myself patterning the colors—green crosses over the tops of the feet, green on the heels, silver on the toes: a fashion statement. If my supplies of iodine and tape can be stretched for another week and my mental balance doesn't tip much further, I'll be fine.

At 4:30 a.m. I hear Dave Morgan, in the tent beside mine, beginning to duct-tape his feet.

Over breakfast Fay himself asks to borrow my tape for a few patches on his toes and heels. I give him the silver, selfishly hoarding the green. Then again we walk.

DEMARCATED by the Goualougo River on one side, the Ndoki River on another, the Goualougo Triangle is a wedge-shaped area extending southward from the southern boundary of Nouabalé-Ndoki National Park. Which means it's ecologically continuous with the park but not part of it statutorily, and it is isolated from the wider world by the two rivers.

The triangle embraces roughly 140 square miles of primary forest and swamp, including much excellent chimpanzee habitat, a warren of elephant trails, and an untold number of big sapele trees, all encompassed within a logging concession held by a company called Congolaise Industrielle des Bois (CIB), the largest surviving timber enterprise in northeastern Congo. With two sawmills, a shipyard, a community hospital, and logging crews in the forest, CIB employs about 1,200 people, mostly in the towns of Kabo and Pokola, along the Sangha River. Although the company has shown willingness to collaborate with WCS in managing a peripheral zone south of the park, especially in restricting the commercial trade in bush meat, concern now seems to be gathering around the issue of the Goualougo Triangle. Mike Fay originally hoped to see that wedge of precious landscape included in the park, but when the boundaries were drawn in 1993, the Goualougo was lined out.

Logging operations were scheduled to begin in the Goualougo in 1998, but CIB agreed to postpone cutting and conduct an on-the-ground assessment of the timber resource and the costs of extracting it. That assessment—a *prospection,* in the jargon of Francophone forestry—will put a price tag on the triangle. Meanwhile the company, in a spirit that mixes



The human appetite *for timber and meat is threatening the forests of central Africa, where logging camps (above left) depend primarily on bush meat for food. Loggers at one camp outside Nouabalé-Ndoki National Park (above) have agreed to spare endangered species and carefully manage their hunts. But "at most other camps anything's game," says photographer Nichols.*

conservation of African forests?

cooperation with hardheaded bargaining, has welcomed WCS to participate in that prospection, focusing on assessment of the area's biological value. Weeks after returning from the Congo, I hear the CIB position put by the company's president, Hinrich Stoll. "You cannot just say, 'Forget about it; it is completely protected,'" he tells me by phone from his office in Bremen, Germany. "We all want to know how much it is worth." Once its worth has been gauged, both in economic and in biological terms, also in social ones, then perhaps the international community of conservationists and donors will see fit to compensate his company—yes, and the working people of Pokola and Kabo, Dr. Stoll stresses—for what it's being asked to give up.

But that talk of compensation, of balancing value against value, of ransoming some of the world's last ingenuous chimpanzees, comes later. As I stroll through the Goualougo with Fay, he turns the day into a walking seminar in forest botany, instructing me or quizzing Madzou and Morgan on the identity of this tree or that. Here's an *Entandrophragma utile,* slightly more valuable but far less common than its close relative *Entandrophragma cylindricum.* Its fruits resemble blackish yams festooned with wiry little roots, not to be confused with the banana-shaped fruit of another *Entandrophragma* species, *candollei.* And here's still another, *Entandrophragma angolense.* What about that tree there—what is it, Morgan? he demands. Um, an *Entandrophragma?* Wrong, Fay says, that one's *Gambeya lacourtiana.* Of course to me these are all just huge hulking boles, 30 feet around, rising to crowns in the canopy so high that I can't even see the shapes of their leaves. Morgan and Madzou are earnest students. Fay is a stern but effective teacher, sardonic one moment, lucid and helpful the next, drawing tirelessly on his own encyclopedic knowledge and his love for the living architecture of the forest. Now he directs Morgan's attention to the fine, fissured, unflaky bark of *Gambeya lacourtiana,* which is not to be confused with the more subtly fissured bark of *Combretodendron macrocarpum,* which is not to be confused with . . . a pile of lumber awaiting shipment from Kabo.

The good news from Day 8 is that Fay finds

OUT OF THE WOODS

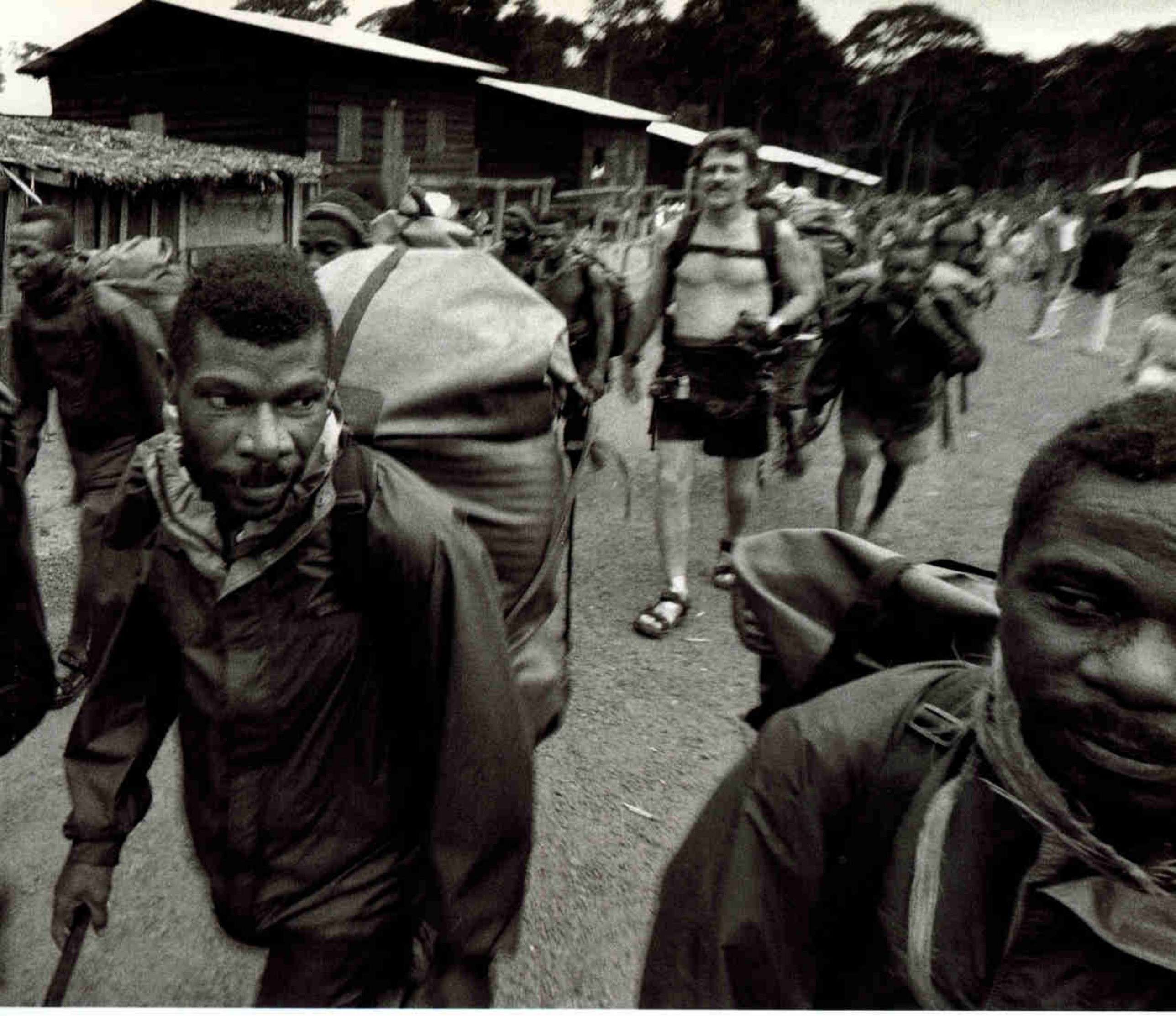
Awestruck by their first glimpse of a town, Fay's companions wandered the streets of Ndoki II, a logging camp, ending the first leg of their journey. "It seems ironic, but the Pygmies loved town life," says Fay—"the hustle and bustle, the loud music, the roads, the machines. Their fondest hope is that their own forest will soon be blessed with such a town." In Part 2, coming next spring, Fay and his team plunge deeper into the unknown forest.



no *P. elata*, no standing gold, no caviar, at least along this line of march in the Goualougo Triangle. The bad news is that there's an abundance of the various *Entandrophragma* species, which are CIB's bread and butter. By the time the prospection team arrives to confirm or modify those impressions, Fay himself will be somewhere else, continuing his own singular sort of prospection at his own pace and scale.

FROM THE TRIANGLE we make our way upstream along the Goualougo River, crossing back into the park. On the evening of Day 11 we're settled near an idyllic little bathing hole, a knee-deep pool with a sand bottom. Peeling away my duct-tape socks, after a gentle soak underwater, I feel exquisite relief. I wash my feet carefully, the rest of my body quickly, and then, given the luxury of deep, clear water, my hair. I rinse my shorts and T-shirt, wring them, put them back on. It's been a good day, enlivened by another two-hour encounter with a group of fearless chimps. For dinner there'll be a pasty concoction known as *fufu*, made from manioc flour and topped with some sort of sauce, plus maybe a handful of dried apricots for dessert. Then a night's blissful sleep on the ground; then fresh duct tape; then another day's walk. Having fallen into his rhythm, I've begun to see why Mike Fay loves this perverse, unrelenting forest so dearly.

Seated beside the campfire, Fay puts Neosporin antiseptic on his ragged toes. Several foot worms have burrowed in there and died, mortally disappointed that he wasn't an elephant. The ointment, as he smears it around, mixes with stray splatters of mud to make an unguent gray glaze. No, he affirms, there's no escaping foot hassles out here. You've just



got to keep up the maintenance and try to avoid infection. When necessary, you stop walking for a few days. Lay up, rest. Let them heal. Wait it out. So he says. I can scarcely imagine what Fay's feet might have to look like before he resigns himself to that.

At the end of Day 13 we make camp on a thickly forested bench above the headwaters of the Goualougo, which up here is just a step-across stream. Our distance traversed since morning, as measured by the Fieldranger, is 42,691 feet. Our position is 2°26.297′ north by 16°36.809′ east, which means little to me but much to the great continuum of data. This particular day, alas and hoorah, has been my final one of walking with Fay, at least for now. (The plan is that I'll return later to share other legs of the hike.) Tomorrow I'll point myself toward civilization, retracing our trail of string and machete cuts to the Sangha River. Morgan and three of the Pygmies will accompany me.

And Fay? He'll continue northeastward and meet Nick Nichols, then loop down again through Nouabalé-Ndoki National Park before heading out across the CIB logging concessions and the other variously tracked and untracked forests of central Africa. The Megatransect has only begun: 13 days gone, roughly 400 to go. Many field notes remain to be taken, many video and audio tapes to be filled, much data to be entered in computers, many miles of topofil to unroll. Then will come the challenge of making it all matter—collation, analysis, politics. When he reaches the seacoast of Gabon, Fay has told me, he'll probably wish he could just turn around and start walking back. □

MORE ON OUR WEBSITE

New photos and fresh tales await you at **nationalgeographic.com/ngm/0010**. Also visit the Wildlife Conservation Society at **wcs.org**.

A SPECIAL PLACE

Sky-High Over the Sonoran

ARTICLE AND PHOTOGRAPHS BY ADRIEL HEISEY

From the open-air cockpit of my home-built plane, my view of a sand dune in Mexico's Desierto de Altar, or Gran Desierto, reveals what can't be seen easily from the ground—radial arms, the hallmark of a star dune. Seasonal winds from three directions sweep this part of the Sonoran Desert, piling sand into a central peak. The forces that have conspired to shape the Sonoran—wind, water, volcanism, plants, and humanity's growing presence—can be seen best from on high.

Hot Spot

As I circle the half-mile-wide maw of Cerro Colorado, one of at least 10 craters and 400 cinder cones that pock Mexico's Pinacate volcanic field, I think of Jesuit missionary Eusebio Kino's treks across this tortured land. When Kino's party crossed the Pinacate in 1701, a member wrote of finding a "hole of such depth that it caused terror and fear." It wasn't Cerro Colorado; its floor is only 13 feet below the surrounding desert. Morning shadows appear to deepen it.





After the Snow
A February storm retreats from Miller Peak in Arizona's Huachuca Mountains, leaving behind a mantle of white and the promise of a greener spring for the desert a mile below. The clouds may look soft and innocent, but they're thick with snow crystals that stung my cheeks as I took off at dawn. I had no assurance that I'd find a hole in the cloud ceiling. If I had played it safe, I would never have seen this spectacle.



Simple, open, and slow—that's how I like to fly. After years as a corporate pilot I grew frustrated with the speed and confinement of large planes, so I built my own. My Kolb TwinStar is lightweight (450 pounds), low speed (35 to 75 miles an hour), easy to fly (I steer with my feet and right leg so I can hold my camera with both hands), foldable (I trailer my plane to shooting locations), and exposed (the engine is behind the wings, and I sit out in front, with no enclosure). Alone in the sky, dangling my feet in the wind, I feel as if I can reach out and touch the places I photograph. Even so, learning to love the Sonoran Desert wasn't easy for me. When I moved to Tucson five years ago, I had just left my job as a pilot for the Navajo Nation in northeastern Arizona, where for more than a decade I had flown over red-rock canyons, spires, and buttes. The Sonoran's worn, repetitive features can't match the topography of the Four Corners,* but there's something about the transience here—the way a sudden shower (right) can transform the place overnight—that grew on me. As I explored the Sonoran from above, I learned that it is unique among North American deserts. It has an extensive coastline (map, below). It's warmer than the continent's other deserts. Much of it receives both winter and summer rain, so it harbors a surprising wealth of plant species. And it can be crowded. The population of Tucson's Pima County, where I shot the photographs above and at right, has tripled in the past 40 years, recently passing 800,000. I've had a hawk's view of the ways humans have left their mark on the Sonoran—suburban sprawl, off-road driving, mining, grazing, woodcutting. I want to share my unusual way of seeing the desert before any more of it changes.

*See "Hawk High Over Four Corners," by T. H. Watkins, with photographs by Adriel Heisey, NATIONAL GEOGRAPHIC, September 1996.







Desert Meets Sea
What look like tire tracks are actually lines of tidal debris on an empty beach near Puerto Lobos, a fishing village on the Gulf of California's eastern shore. After an evening flight exploring bluffs and dry gullies, I camped on the beach with my plane. When I flew the next morning, I saw rays and dolphins gliding through the water—welcome signs of life in the increasingly overfished gulf.





A Matter of Scale

Monolith of lava, Courthouse Rock rises higher than the Empire State Building over the western Arizona desert-scrub. Geologists call the structure a volcanic neck—the lava that forms it filled the throat of an ancient volcano. The 15-foot-high flower stalk of an agave is a

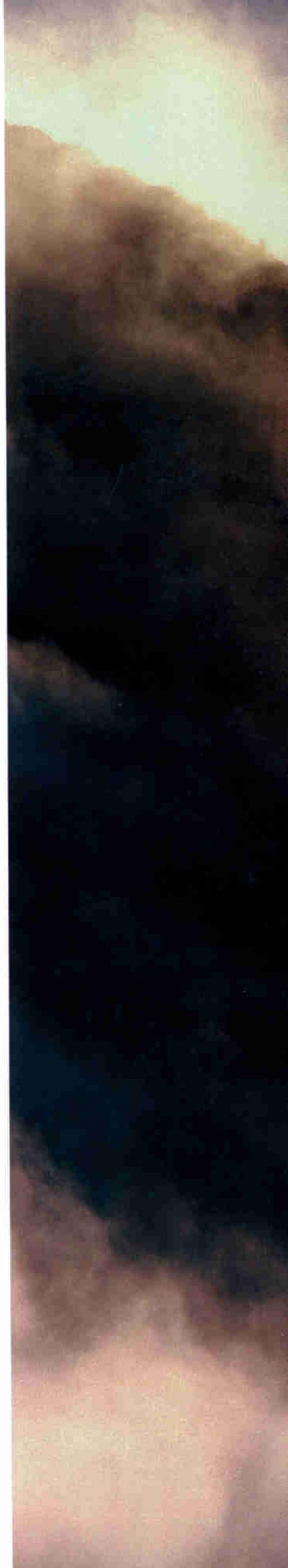


skyscraper on a different scale. Just before they die, agaves send up blossoms, which bats, hummingbirds, bees, and moths pollinate. To make this photograph, I had to swoop nearly as low as a bat, below a hundred feet, where I have little margin for error.

Waiting for Water

Saguaro cactuses in the cooler uplands of Arizona's Superstition Mountains (right) prefer sunny, south-facing slopes. The north side offers more moisture, but winter frosts can kill seedlings. When rain comes, desert plants seize the moment. After a few well-timed storms, wildflowers fill what was once a dusty basin in Sonora's Pinacate Biosphere Reserve (above). I lingered for the color—green veins are mesquite trees and orange patches are blooming globe mallow—and for the uncommon delight of flying through fragrant space.







A River's Salty End

Tapped by human need, the Colorado River meanders through a wide delta in Mexico before it empties into the Gulf of California. Farms and cities upstream in seven U.S. states have claimed most of its water for uses such as irrigation, sanitation, and swimming pools. At this point, only miles from the gulf, the channel is full of high-tide seawater. What was once a fertile wetland along its banks is now dry and encrusted with salt.



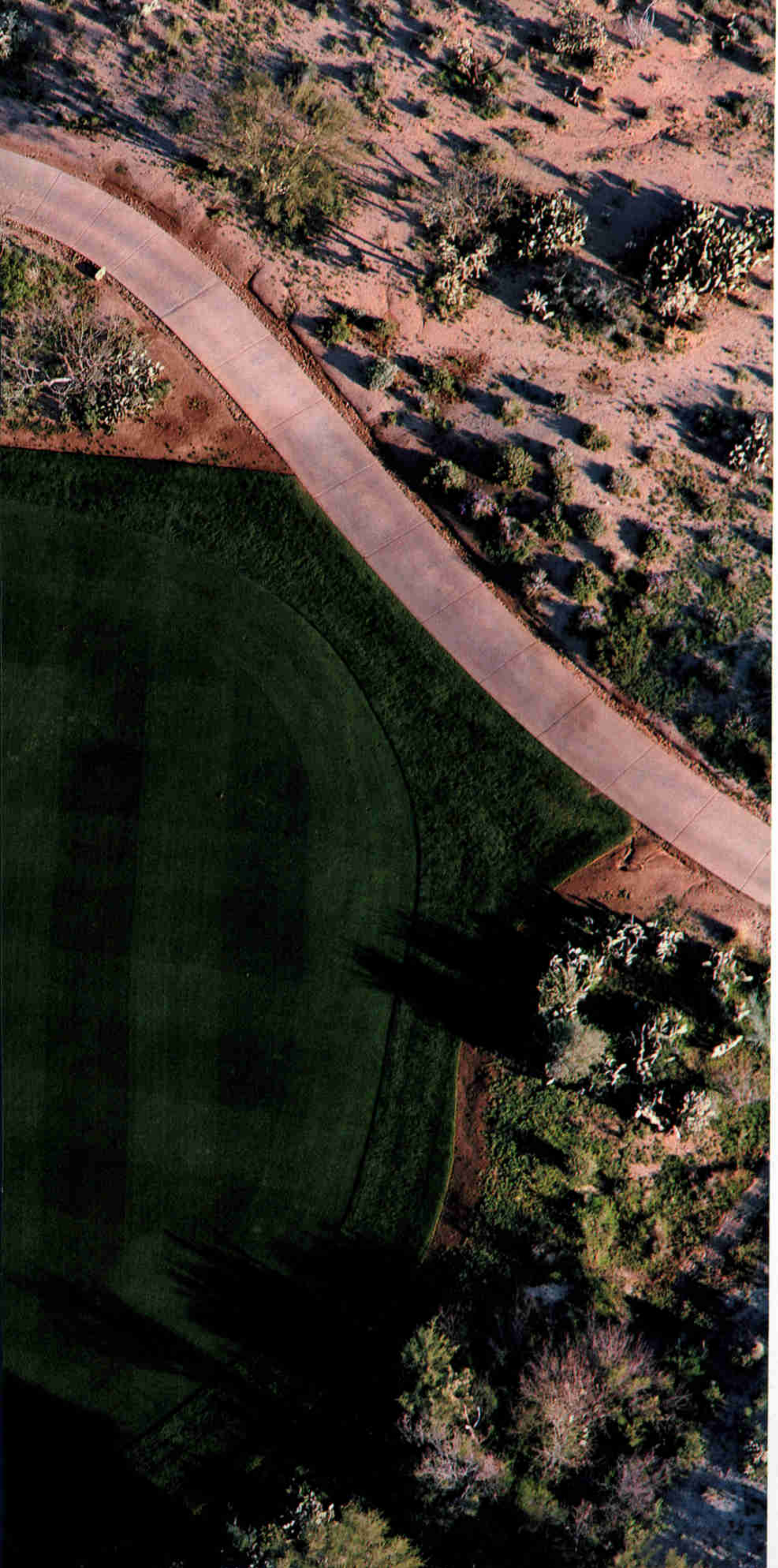
The Human Footprint

The promise of year-round golf draws thousands of retirees to planned Sonoran communities like Arizona's Rancho Vistoso (right). Houses here straddle natural washes and are packed together to preserve open space, but new construction projects keep claiming desert land. Relics of a more modest boom huddle on a butte overlooking the now dry Gila River on the Tohono O'odham Indian Reservation (above) near Gila Bend, Arizona. Canals and irrigated fields sustained the Hohokam people 700 years ago.









The Enduring Desert

Early one June morning I came upon several coyotes on a golf green near Tucson. I throttled back and circled to watch them. They seemed to be playing like friendly dogs, occasionally stopping to lap at pools of water from irrigation sprinklers. Then one mounted another, and I realized that what I thought was merely play was courtship and mating. I smiled and banked away. Even in our most manicured spaces, the desert renews itself. □

MORE ON OUR WEBSITE

How did author Adriel Heisey photograph the Sonoran Desert while piloting a 450-pound plane? Find out at **nationalgeographic.com/ngm/0010.**

To Americans,
they appear
totally Italian.
To Italians,
they're instantly
recognizable as
Americans.
To themselves,
they are sure
only that they are

Boston's North Enders

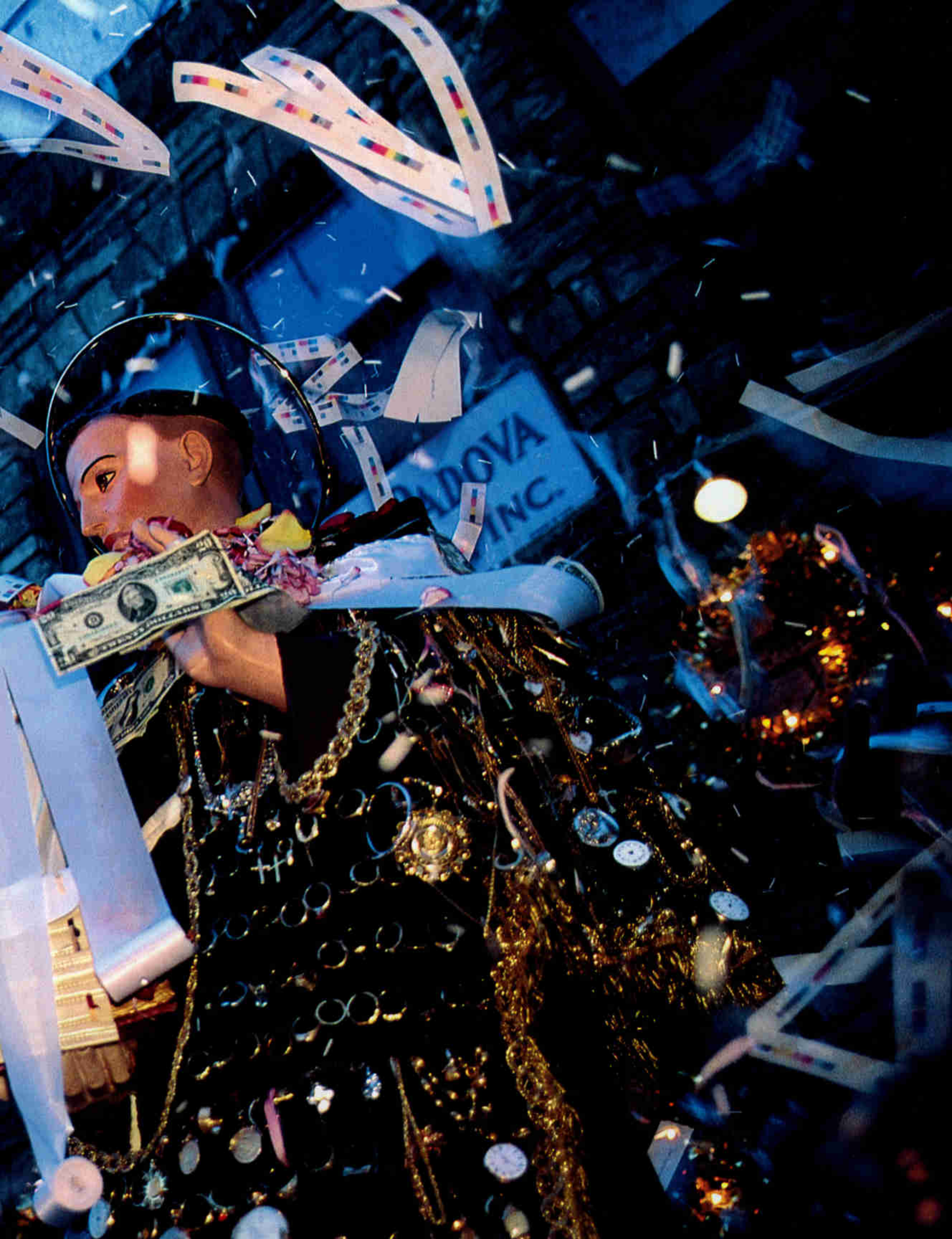
By Erla Zwingle

Photographs by William Albert Allard
NATIONAL GEOGRAPHIC PHOTOGRAPHER

Born of Italian parents, bred in the North End, lifelong friends and World War II veterans Pat Barrasso and Freddy Bruno meet weekly to play cards and reminisce. Their neighborhood is still so vibrant, says Bruno, at right, "It kinda keeps you alive."

Keeping the Faith

Reverence and revelry mix during summer festivals



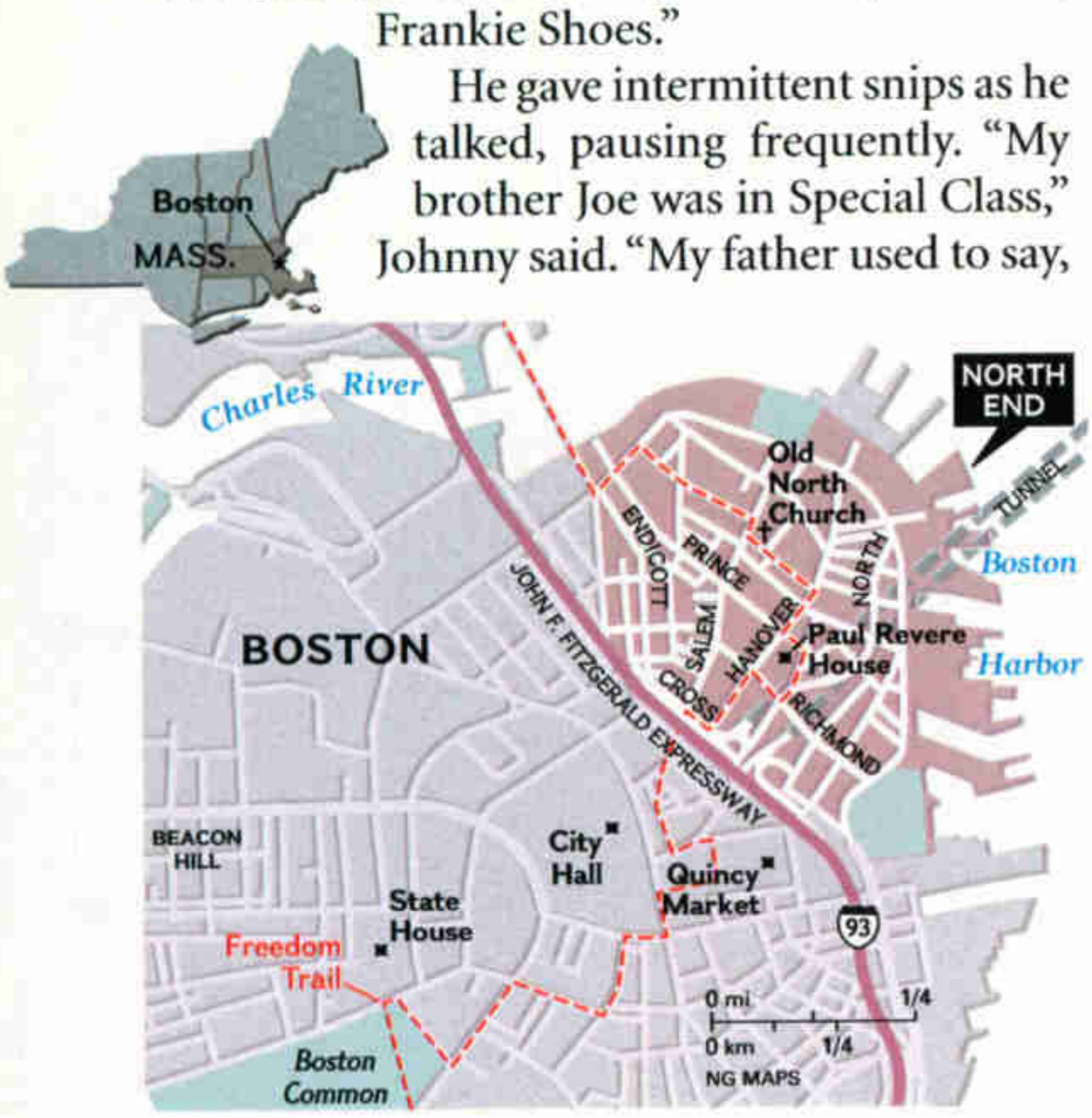
honoring saints like Anthony, whose statue bears offerings that request—or repay—miracles.

Outside Johnny & Gino Hairstyling on Hanover Street, the late September morning moved from soggy clouds to brilliantly clear, with a fresh breeze off the harbor and sun glinting from the golden domes of Boston's colonial buildings. Inside, Johnny "Shoes" Cammarata was putting the finishing touches on Rico Federico's trim, while assorted customers waited their turn.

"I was born here," Johnny is saying in his broad Boston accent, "but I had to speak Sicilian at home if I wanted to eat." This would be an important point: His silhouette is clear evidence that his enthusiasm for talking is matched only by his passion for home cooking, not surprising for a man who was born on the kitchen table. "And I'll die on the table," he says cheerfully, "with my face in a plate of lasagna. With two meatballs, one on each side."

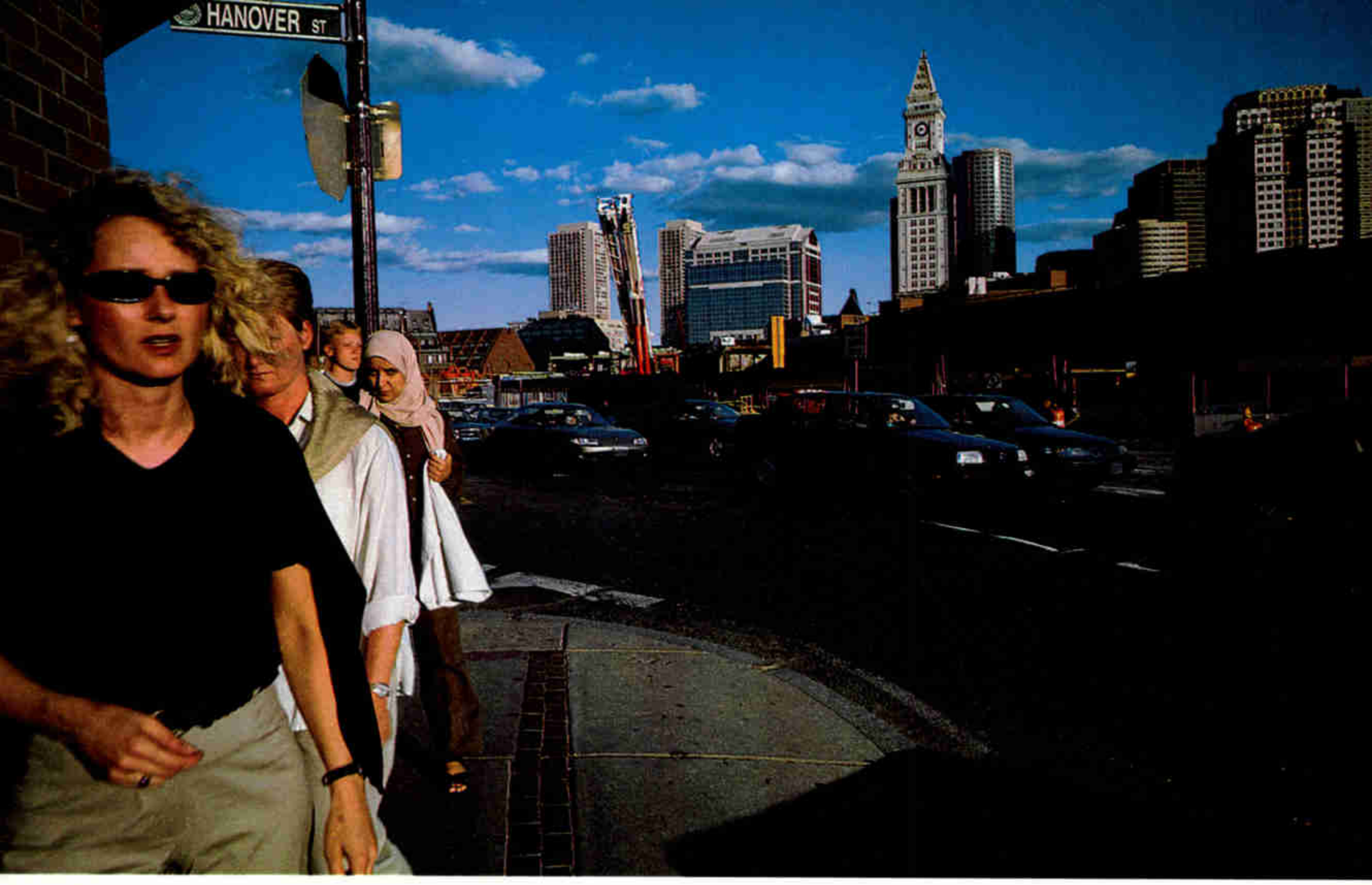
Why would a barber be nicknamed Shoes? Because his father was a cobbler, obviously. "We were all called Shoes," he said. "Joe Shoes, Frankie Shoes."

He gave intermittent snips as he talked, pausing frequently. "My brother Joe was in Special Class," Johnny said. "My father used to say, 'Joe, I'm so proud of you. You're in *Special Class.*' And I'd crack up. Joe'd say, 'If you ever tell, I'll kill ya.' My father didn't know it was basket weaving. . . ." Parental discipline? Swift and accurate. "My father split my head," Johnny says, breezing on. "He took the hammer—he was a cobbler, thank God he wasn't a butcher! I was supposed to clean the shop. Yeah, yeah, yeah. Didn't do it. Bam! Hammer on the head. 'Now go see your uncle'—he was a barber. He cut around the spot and took a lemon and squeezed it on my head. How I ever lived. . . . I said, 'You didn't even think twice, Pa.' I loved him. I LOVED him."



The North End, a mere square mile, is the original Boston. Yet perhaps more than any of the myriad Little Italys scattered across America from Millinocket, Maine, to San Diego, California, it has always possessed a powerful mystique. When the Prince Spaghetti Company aired an ad showing an Italian mother leaning out of her North End apartment window calling her son to dinner—"Anthonyyyyyy"—it poured a rich sauce of nostalgia over that imaginary plate of pasta. Who were these people?

The North Ender is a complex breed composed of Mediterranean emotion, Yankee drive, and a seemingly limitless passion for their own. To be able to say you're a North



Ender, I soon discovered, would put you several notches higher than Phi Beta Kappa, a 32nd-degree Mason, and five Nobel Prize winners picked at random.

North Enders inhabit a sort of homeland where everybody has known one another from birth and everything was shared, from mothers to memories, spare sofas to Sunday dinners; five cents for a shoeshine, the bathhouse on Saturday morning, the strap to the behind, and an instinctive sense that what makes a family work also goes for a whole neighborhood. "We were taught love and respect," said Freddy Bruno, 87, at the Bella Fuma Cigar Shoppe. "Before we ate on holidays, we had to kiss our father's hand and our mother's hand. OK, you got the strap. But you see, I loved it. There was so much dedication and so much strictness. So much learning how to live decent."

Magnet for immigrants since its settlement in 1630, the North End is evolving from ethnic enclave to haven for young professionals who crave historic charm close to downtown offices.

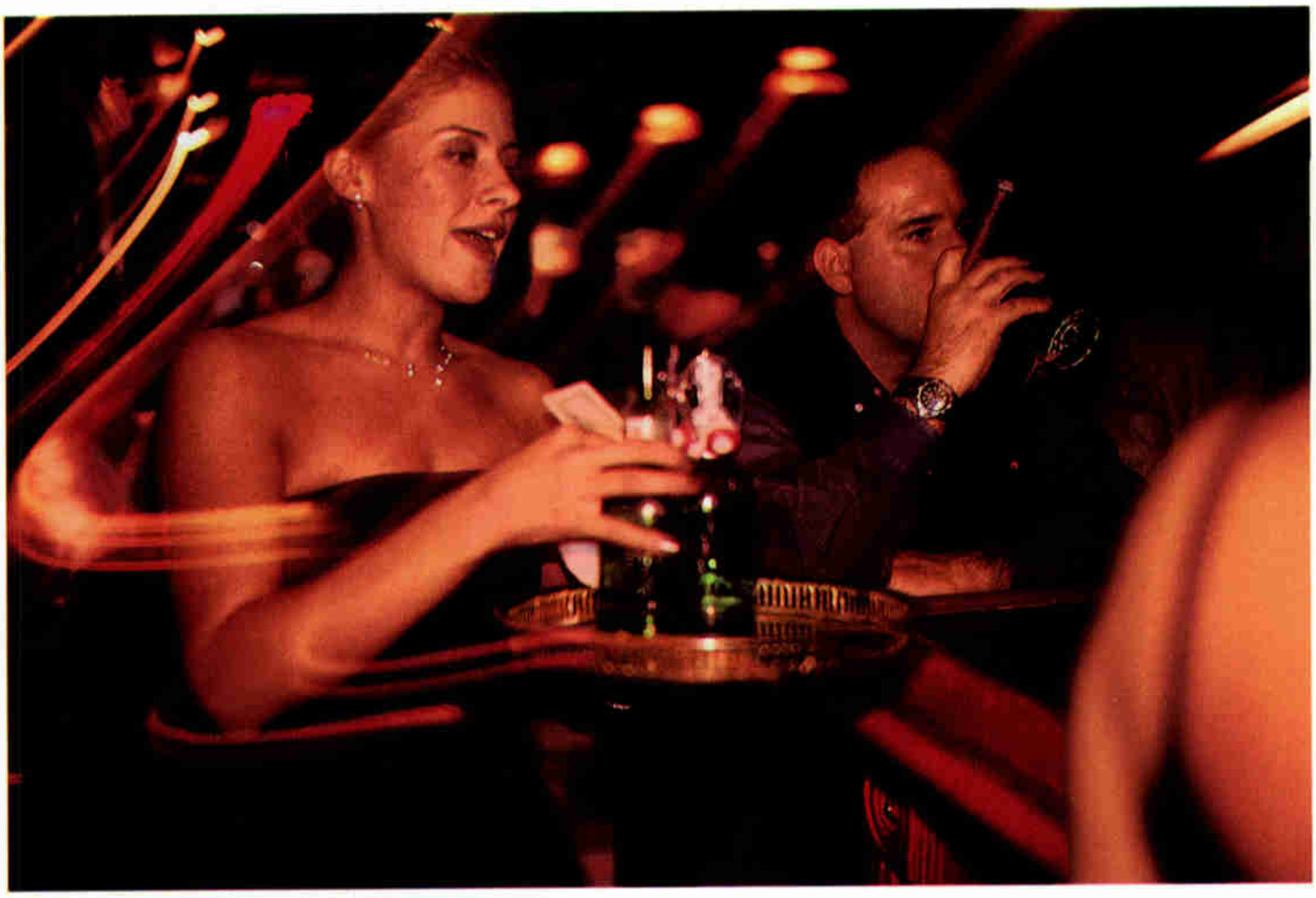
AN IDEAL DAY—and there were many of them—involved a leisurely round that became ever more complex as I discovered new places and met new people.

Up before dawn, and through the dark streets—Richmond, North, Prince—past the Paul Revere House and the Sacred Heart Church. Prince and Salem Street was my goal: Parziale's Bakery.

It isn't even six o'clock yet, but Freddy Parziale is already seated majestically on his folding chair in the corner, supervising the distribution of bread just coming out of the ovens. Carefully counted, hundreds of the long crusty "bastonas" in their paper grocery bags are ready to be taken to a good number of neighborhood restaurants. Freddy, graying, heavy jowled, wreathed in Benson & Hedges' best smoke, is watching everything.

"Bakers in the old days would die young," Freddy was saying. "Too much work. Too much boxes, moving them back and forth. Thank God them days are over." His family owned bakeries all over the North End; this bakery is the last of the bunch.

A thin old man came in to buy some bread. He seemed angry. He went on and on in dense Neapolitan dialect. When he left, I asked Freddy what was wrong. He sighed heavily. "He used to work here," he explained. "He says the bread wasn't cooked Sunday. He says when the three of us worked here, it came out



"I was born here, but I had to speak

beautifully. Yes," Freddy shrugged, "but we didn't make this much bread. He's like my father, for crying out loud."

The North End was English first, then American, then Irish, then Jewish. About 1870 came the flood of Italians, driven out of southern Italy by a catastrophic combination of poverty, disease, natural disasters, and political and economic oppression—a situation so extreme that one scholar has called it "well-nigh expulsion." Between 1876 and 1976, 26 million Italians emigrated, the largest exodus ever from one European nation.

More than five million came to the United States, and what they found was not entirely unfamiliar. In America they also encountered privation, crushing labor, and outright racism. The struggle to adapt was a far more complex process than some simple fable of checkered tablecloths and "That's Amore"; it was an epic of tenacity and compromise. Italians, in fact, were among the ethnic groups with the highest return migration rate. In a world strained by poverty and fear, your family was the only thing you could trust. And the North Enders were a family. "Everybody needed each other," said Freddy Bruno, "so they were close. There was no such thing as calling 911."

At its peak in the thirties and forties, there were as many as 42,000 people in the neighborhood, which was 95 percent Italian. Since then the population has shrunk to 12,500 residents, of whom only about 30 percent are Italian. The streets now are busier with outsiders, either tourists or roaming prides of chattering young people who crowd the restaurants. The tight weave of the North End fabric is beginning to fray. "Today I could walk out," one indignant old man told me, "and pass 200 people and not know who they are."

Armed with a hot fruit turnover just out of the oven, I'd leave Parziale's Bakery and head for the Caffè Paradiso on Hanover Street. Adriana De Stefano-Federico or her

Inescapable as the scent of a cigar, *la vita bella* suffuses the clubs and narrow byways of Boston's Little Italy. Outside Pagliuca's restaurant, an impromptu concert draws a crowd. Says Joe Pagliuca, at far right, "This music is from the heart."

brother, Oscar, would be busy fixing cappuccinos and greeting customers. The TV behind the bar showed rioting in East Timor. "We don't need to see this depressing garbage in the morning," Oscar commented as he headed downstairs. "They should put on positive garbage."

Their mother, Antonietta, a retired teacher, dark-haired and sad-eyed, was usually sitting at a small table reading the Italian newspaper *La Repubblica*. One morning she overheard me speaking a few words of Italian to Adriana. She asked me why. I replied that I spend much of each year in Italy.

"What a beautiful destiny you had," she said without smiling. "An American going to Italy. I had the opposite luck. My husband was crazy in love with America. I've been here more than 30 years. My *body* is here," she corrected herself. "But my ideas are in Italy."

I hesitated, sensing tricky terrain. But she didn't hesitate at all. "The name, America—where does it come from?" she asked rhetorically. "An Italian. Italians have done everything. But no, I can't find joy here. Children here have grown up with this religion."

Religion? "The religion to be free, to do what they want," she said. "This country is the source of everything bad."

The immigrant experience is rich with ironies. A poverty-stricken family may go to a new country with the clear purpose of making a better living, only to find that in the process other values have become degraded or even destroyed. They are double exiles, banished from their own past and their children's future.

I felt embarrassed to hear Antonietta speak so bluntly about the flaws in the vaunted American dream. Yet she wasn't alone.

"My father brought us here from Salerno in 1955," Matteo Gallo, a real estate entrepreneur, had told me over dinner one evening at Il Bacio, just across the street. "There were mudslides, and everything got destroyed—the house, the stores, and we didn't have insurance. But my father hated this country. He didn't like the American mentality, not having respect for

Sicilian at home if I wanted to eat."



Destined for the Spit

A young pig is deboned at Taverna Toscana,



where succulent *porchetta* and other specialties recall the owner's youth on Italy's Amalfi coast.



"Bakers in the old days would die young,"

one another. The whole motivation for everything was the dollar. He used to say, 'If I die in this country, promise to take me back to Italy.' Well, he died in Italy, so from that point of view he was happy. But I think this is the best country there is." Still, Matteo's dress shirt, silk necktie, and tailored suit were all Italian. So was his underwear, he didn't mind telling me.

I asked Adriana whether she felt more Italian or more American. She thought for a minute, then replied that she had come to Boston in the early sixties when she was almost 12. "You had to prove yourself, and you had to prove yourself three and four times harder because you spoke with an accent," she said. "Now if you have an accent, it's, 'Oh wow, how cool.' Before, it was, 'Oh, what is she? A guinea, a wop.' They didn't look on you as the person you are." Now, when she goes back to Italy on vacation, she says people in her town treat her like an American tourist.

"I wouldn't eat anybody else's bread," says Freddy Parziale (right), whose family bakery has satisfied robust local appetites for nearly a hundred years. Pride is also apparent at Modern Pastry, where hand-painted marzipan beckons like forbidden fruit.

I ALWAYS HAD TO STOP by Johnny's shop, even if it was way up at the end of Hanover Street. I'd perch by the big window by his chair, and he'd start: "Whaddya wanna know?" There was always an assortment of clients and friends who seemed to regard Johnny and Gino's place as a spare room to their own homes. After only a few days I had heard the theme song and its variations: "We never locked our doors. . . ." "Everybody knew everybody. . . ." "It was safe. . . ." "Everybody shared. . . ." And Johnny's favorite phrase, which soared as a sort of cadenza above the swelling chorus: "We had nothing, but we had everything."

I discovered I had an insatiable appetite for these reminiscences, in which the North End glowed like some Norman Rockwell vision of life, with garlic and tomatoes; "the last community in the country," Johnny called it. Stories about how families would buy the Zinfandel grapes in October and

make their own wine: "Everybody made wine," one man recalled. "After the pressing they'd throw the grapes out on the street. You could smell that odor all over the North End." Playing marbles on the manhole covers, selling papers for a week to have a dollar to give to your mother, hanging around the Quincy Market to make extra money for unhitching the horses from the vegetable wagons and riding them back to the livery stable. ("Oh, the horses didn't need us," Johnny admitted. "They could get back there all by themselves.")

There were also the bootleggers, numbers runners, and the gentlemen associated with the Angiulo family, now dispersed, which controlled the neighborhood from the early fifties until the FBI intervened in 1983.

"In our area it was mostly bookmaking," Johnny told me. "I could tell you they killed a guy every week—naahhhh, it wasn't like that. We respected them, and they respected you. They were the ones with the money. If we kids were selling chances, they'd buy a whole book. They were good to us, I'll be honest."

I had no reason not to believe him. But when families tell their own stories, they sometimes leave something out. So you ask the neighbors. "People saying that Jerry Angiulo kept the North End safe—that was a myth," says Shelley Murphy, who covers organized crime for the *Boston Globe*. Though there were turf battles between the Italian and the equally violent Irish factions, especially in the sixties and seventies, homicides in the North End itself were rare. Police statistics show that between 1973 and 1993 reported murders ranged from zero to four a year. But while larceny doesn't have the drama of death, it's an interesting indicator of Angiulo's control of the neighborhood: Robberies, burglaries, and assaults all dropped after he left 98 Prince Street. In 1983, the year he was arrested, there were 1,869 larcenies in the North End; a decade later there were 1,010.

One morning I made a little detour to the Nazzaro Community Center, once the neighborhood bathhouse and gym. I was finally

Freddy was saying. "Too much work."



going to meet Josephine Zizza, and it had taken some time to catch up with her. Josie (she was christened Generosa) is small, wiry, brown-haired, and at 91 still several steps ahead of me. She was too polite to show that she was aware of it.

"I didn't go to college," was the first thing Josie told me, looking at me with bright yet wary eyes. "I really loved school; not that I want to brag, but I was on the honor roll. But I couldn't go on to ninth grade because I came from a family of 12 children, and when I was 14, my parents insisted that I go to work." Large families always needed extra income, yet scholars have also commented on the resistance that many Italian immigrants showed toward education, convinced it was destructive of the family's authority. Josie was one of its statistics.

She went to work in a paper box factory, a candy factory, and finally a kosher meatpacking plant, all in the North End. She married when she was 25, had four sons, and kept working until she was 66. She'd probably still be at it, "but my sons insisted I retire, so I started doing volunteer work." Josie is not inclined to flights of nostalgia, like a certain tonsorial artist. "My brother didn't finish school," she continued. "He ended up as a truck driver. I could have killed him. My father told my mother, 'Let her stay in school,' but oh, no. Her son had to go to college. The Italian people and sons. My father was much more open-minded than she was. My younger sisters all graduated high school though. I forced them to go."

Nancy Caruso, some two decades younger than Josie, is just as small, brunette, and determined, but she's on the other side of the statistics. Oddly, I also met Nancy at the Nazzaro Center, but it was at a heated community meeting to discuss the nine-year-long impact of the "Big Dig." This is one of the largest public works projects in American history and consists of dismantling the John F. Fitzgerald Expressway and replacing it with a tunnel. The disruption this is causing in the North End is intense, and Nancy is dedicated to keeping the

"Now if you have an accent, it's, 'Oh wow,





how cool.' Before, it was, 'Oh, what is she?'"

neighborhood's needs foremost at City Hall.

Nancy, who was called Annunziata in her Sicilian mountain village, came to America in 1938. She was nine and spoke not a word of English.

"We lived in a cold-water flat at 136 Prince Street," she recalled. "The water would freeze in the glass at night." Her father sold fruit from a stand, and her mother worked in the factories. When Nancy announced that she wanted to go to college, "my uncles said, 'She can work in the factory and then get married—who does she think she is?' My mother said, 'She's the daughter of Carmelo Caruso.'"

The deal was this: "I could go to college," Nancy went on, "if I got all A's. I said, 'OK.' And I had to pay my mother $10 a week. I said, 'OK.' I had to work 20 hours a week to make that. 'And you have to pay all your expenses.' I said, 'OK.' It was easy for me because I was young, innocent, and stupid. I wanted it so bad."

Nancy doubled her bet, earning $20 by working 40 hours a week plus going to school. "I went home Saturday night, gave $10 to my mother, and then I had $10. I was going on adrenaline for four years. Then I got TB and spent a year in the hospital, flat on my back." Undaunted, she got a job teaching at Northeastern University. When she retired 36 years later, the daughter of Carmelo Caruso had long been a full professor.

A third-generation "angel," Lisa Barone (left) waits to recite a prayer at a festival honoring Sicily's Madonna del Soccorso de Sciacca. Tradition also ties bride Lynn Bova to the North End. "My parents are here, and we're very, very close," she says.

DOWN SALEM STREET and a look into Polcari's Coffee. This little store has been specializing in coffee, tea, spices, and extracts for baking since 1932. In fact it's the oldest store of the same business, family, and location in the North End. Marie and Ralph, brother and sister, have achieved this record by keeping up with the times. They still sell classic Italian items (dried chickpeas and lentils from huge plastic bins, oregano and basil, and espresso beans),

Old World Echoes

North End alleys that once rang with the shouts of



immigrant children are quieter now, as the area's Italian-American community dwindles and ages.

but they also offer the unroasted coffee preferred by some of their non-Italian customers, as well as cumin, coriander, and cayenne.

Many North Enders are shocked at how fast the neighborhood is changing. The North End is "hot." It started in the early eighties, when an area once considered a slum suddenly appeared as a great place: College students wanted a safe neighborhood, young couples who had traveled liked the European atmosphere, and driven professionals wanted to be able to walk to their jobs in the nearby financial district. Rents have shot up, and the resulting exodus of families has meant that schools and stores, and even churches, are closing. Shops keep turning into restaurants, and some of them, despite names like Rabia's and Il Villaggio, are actually owned by non-Italians, their kitchens full of anxious, silent workers from North Africa and Central America doing the work that their predecessors once were lucky to find. Real estate speculation, powerful as a tectonic plate, is moving everything around. "Everybody's going to get what they can while they can," one person told me. "When I was a kid," said another, "there were a hundred butchers and five restaurants. Today there are five butchers and a hundred restaurants."

A stroll in the snow, a moment in the sun—life shifts like the seasons in the North End. "When I was a kid, we needed each other so we helped each other," says one resident who longs for the past. "It was beautiful." For many North Enders it still is.

How does Marie Polcari regard the newcomers? "We welcome them," she said. "For us it's interesting, it's educational. Change is inevitable," she said. "This can't always be Italian. The old-timers are gone."

My last stop was almost always the Bella Fuma Cigar Shoppe, where Lynne Poland and Freddy Bruno —young and old, newcomer and native— represent the closing of the circle.

"Today I could walk out and pass 200





people and not know who they are."

"Beautiful Smoke" is on Cross Street, at the farthest edge of the North End, beyond which there are only dragons and sea monsters. Like Johnny Shoes, Lynne runs something between a business and a clubhouse. She has blond hair, an eager smile, and a passion for cigars. Not Italian, she came to the North End from California when she was 16. Freddy once drove a beer truck and now helps out in the afternoons. Freddy may be small, but he was a champion junior lightweight boxer in the Army, and he's held his own everywhere from scuffles on Endicott Street to Omaha Beach.

Sometimes he talks to Lynne about his dream of seeing Normandy again. They seem such an unlikely pair—the scrappy lone girl with possibly more determination than business skill and the bright-eyed old man in a crisply ironed shirt, whose children are grown and whose wife has health problems. But they both love the North End, and—true North Enders—they love being in it together.

One mellow October afternoon Lynne organized a little surprise for Freddy: A cake and candles, numerous friends, a cooler of drinks, and a large floating balloon she had tied to a chair—Happy Birthday. He was turning 87, and he'd never had a birthday party in his life.

Freddy was stunned. It was a glorious afternoon, full of laughter and *very full of smoke*. The next day, Lynne told me, she asked Freddy what he wanted to do with his balloon. He looked perplexed.

"Why don't we set it free?" she suggested. That sounded good. So he untied the balloon and went out on the sidewalk.

"Where do you want to send it?" Lynne asked him. "I know," she said. "Let's send it to France." Freddy smiled. And so he let go of the string, and they stood there side by side, watching the balloon float away. "Good-bye," Lynne called. "See you next year."

One lady told me that she had always thought that every neighborhood was like the North End. Now there's a nice idea. □

MORE ON OUR WEBSITE

Meet more of the residents of Boston's North End at **nationalgeographic.com/ngm/0010.**

WILD

THE CREATURES OF BORNEO'S RAIN FOREST GO AIRBORNE.

ARTICLE AND PHOTOGRAPHS BY TIM LAMAN

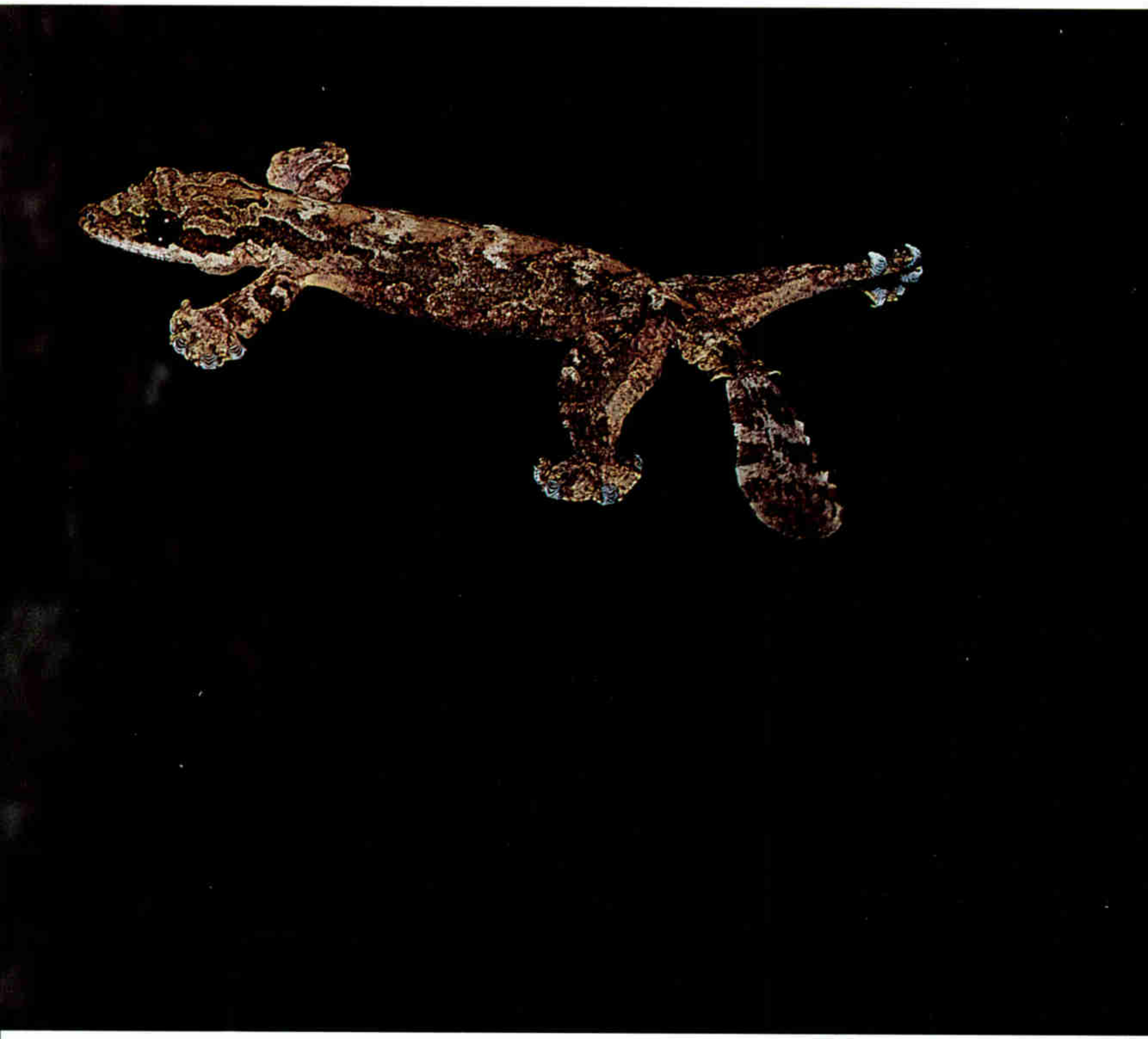


CHRYSOPELEA PARADISI
A ribbon-flat paradise tree snake zips through canopy airspace. This snake is but one of many gliding animals I have spent months pursuing and documenting.



PTYCHOZOON KUHLI

Kuhl's flying gecko is a nocturnal predator that sits in wait for insects on a tree branch (right). When startled, or perhaps just to move to a new foraging spot, it launches into the air (above, at right). With stroboscopic flash I captured two images of the same lizard on one frame, revealing its change in posture as it comes in for a head-up landing. Webbed toes and flanges of skin on legs and tail help provide camouflage and increase surface area for gliding. On longer glides, air pressure also spreads flaps of skin that are normally folded under its body.





PETAURISTA PETAURISTA

Borneo's enigmatic rain forests, like this lowland forest in Gunung Palung National Park, Indonesia, still hold many secrets. Little is known about the lives of most of the animals pictured in this story. The red giant flying squirrel (right), photographed high in a wild mango tree from a canopy blind, can grow to more than three feet long, including its tail. It is the largest of Borneo's 14 species of flying squirrels. Similar species may have slightly varied diets and may prefer different levels of the canopy. All these silent gliders of the forest night are extremely difficult to study in detail.



The snake moved along the tree branch in the dappled light of Borneo's rain forest. Suddenly it dropped over the edge, just holding on by its tail, and then pushed off into the damp air. It changed shape as it began to drop, ribs spreading and body flattening as it swam through the air. This would be the worst nightmare of someone afraid of snakes, but to me it was a part of a wild dream come true.



Since I first went to Borneo in 1987, I have been curious about the island's extraordinary diversity of gliders. It's not that they are easily noticed. Most of them have cryptic coloring, are nocturnal, or are hidden in the high canopy. Over the years as a field biologist I had exciting, fleeting encounters with them: A giant flying squirrel as big as a T-shirt, glimpsed soaring at dusk. The flying gecko that glided into my jungle hut and landed on my back. Two paradise tree snakes on a branch a hundred feet up in a tree next to the one I was climbing. A flying lemur letting out an unearthly scream as it eluded an attacking hawk.

These gliding animals can't propel themselves through the air like birds or bats. They shift body weight subtly or adjust tails and limbs to steer a controlled flight path through the canopy labyrinth. More than 30 gliding species can be found in Borneo alone. Why is this island so rich in gliding species while other rain forests like the Amazon have none and African forests harbor just a few gliders? I believe it is because Borneo's forests, as well as others in Southeast Asia, are different in one important way: They are dominated by giant dipterocarp trees, which fruit infrequently and unpredictably and crowd out other trees. These conditions appear to make food sparser in Borneo than in other rain forests, forcing the forest animals to range more widely. What better way than to glide? It allows them to go from tree to tree without making the long trip down to the ground and back up again. This need for efficient canopy travel can explain why gliding has emerged in such a variety of animal groups, each evolving unique structures to glide with, from the exaggerated webbed feet of flying frogs to the skin membranes of the flying lemurs. Locating and observing these gliders in the wild was a challenge. I climbed 150-foot trees and trekked the jungle day and night. Only slowly, slowly, did the timeless forest reveal its secrets.

MORE ON OUR WEBSITE

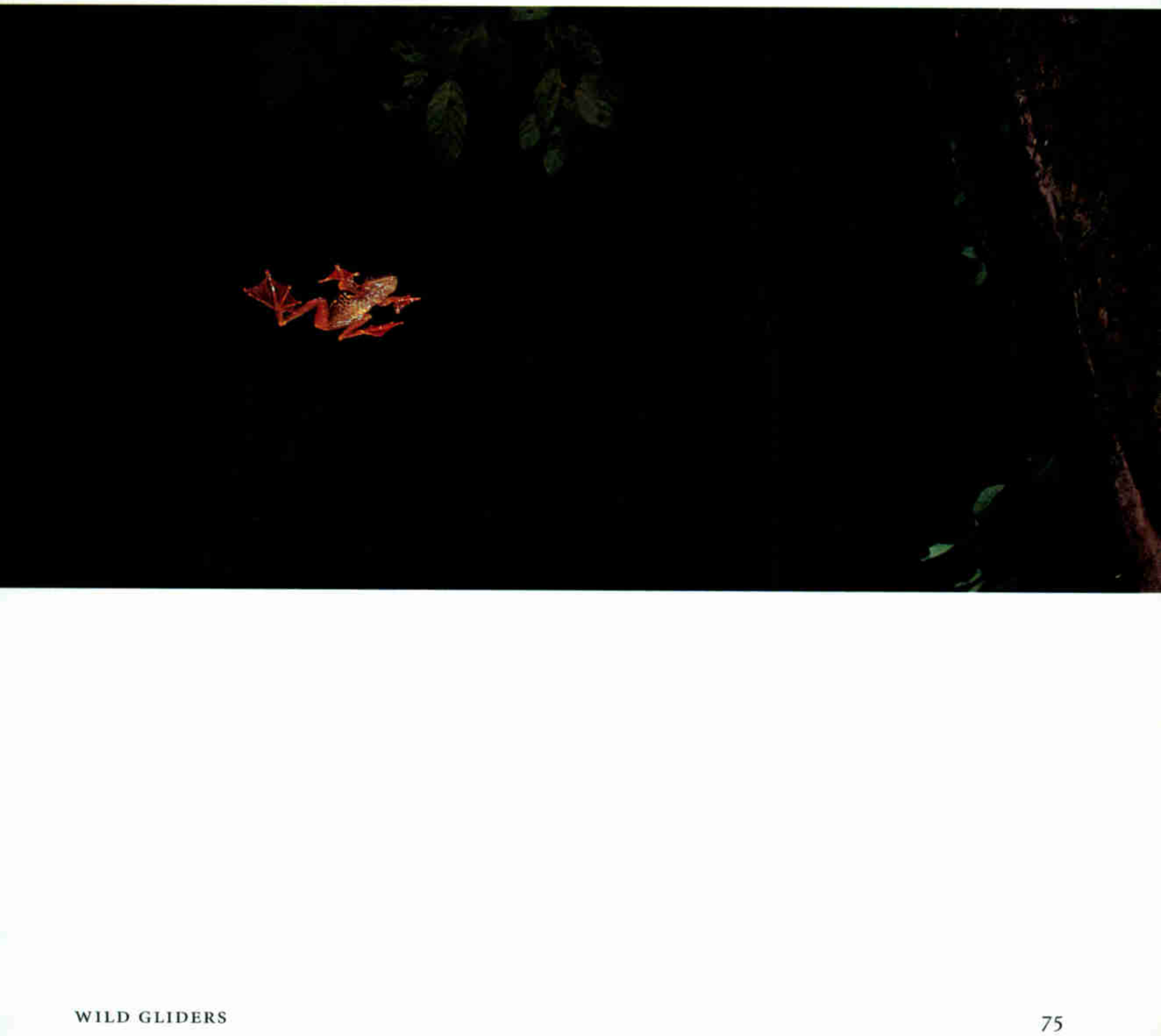
Tim Laman narrates a multimedia show featuring Borneo's gliders at **national geographic.com/ngm/0010**.





RHACOPHORUS PARDALIS

Borneo's flying frogs go airborne to move from tree to tree or descend to breeding sites. Loose flaps of skin on their limbs as well as long, webbed fingers and toes give them the lift they need in order to glide. Adhesive pads help them nail tricky landings on tree trunks or foliage. Many species of tree frogs can hold their limbs out to make descents without tumbling through the air. But only those that have evolved extensive webbing like the harlequin tree frog (left and below) can truly glide. With their webbed hands and feet for airfoils, these frogs not only glide but even make banked 180-degree turns in midair.



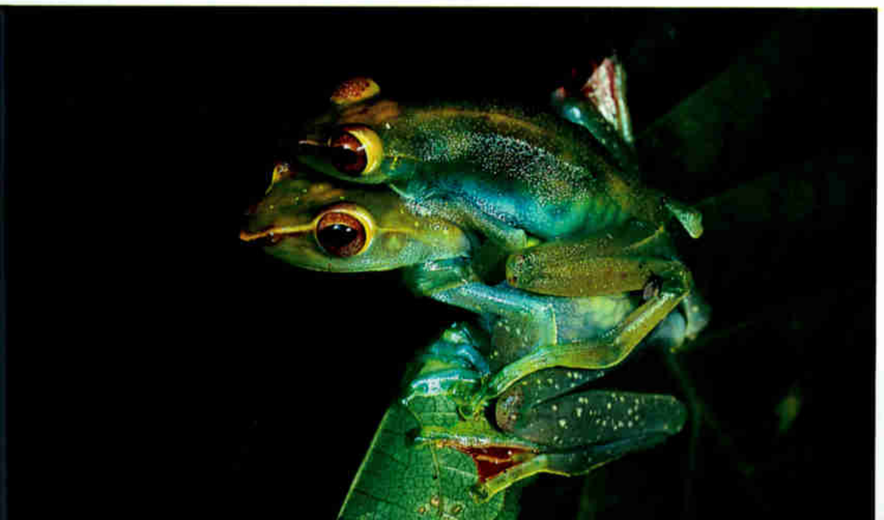


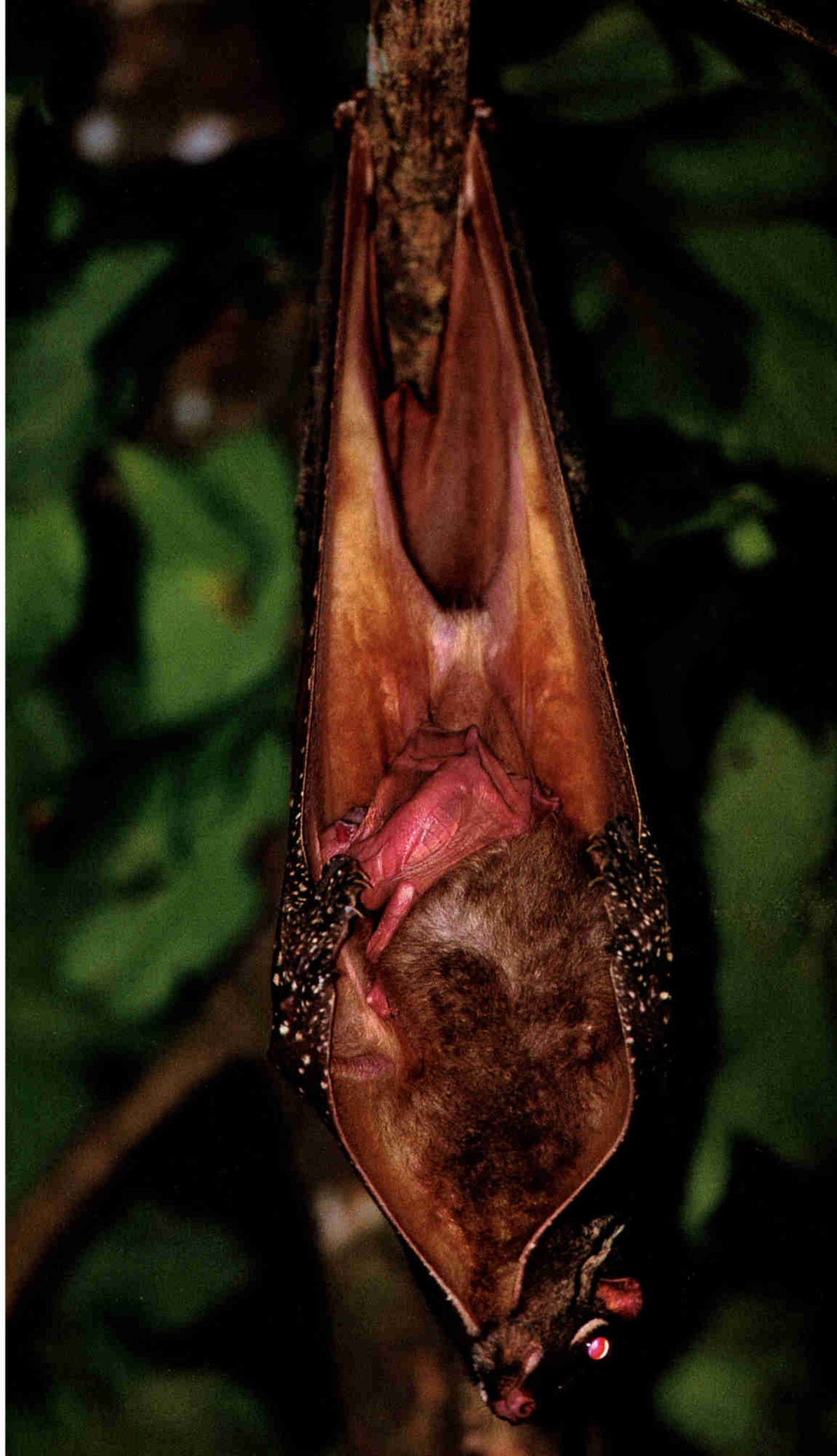
RHACOPHORUS NIGROPALMATUS (TOP)

RHACOPHORUS DULITENSIS (OPPOSITE)

A flying frog (above) glides down to a wild-pig wallow. Frogs gather on branches above such murky pools to breed and lay eggs. The pools then make ideal habitat for tadpoles, which drop into the water when they hatch. This largest of Borneo's flying frogs was discovered by 19th-century naturalist Alfred Russel Wallace. Jade tree frogs, a little-studied species, have webbed fingers and toes, but scientists have yet to catch one gliding. A female (right) prepares to lay the white eggs visible through her transparent skin while the male on her back waits to fertilize them. Once frogs climb into the canopy, they rarely descend except to breed.









GALEOPTERUS VARIEGATUS

Waking at dusk to begin a night's foraging, a female flying lemur, or colugo, hangs from her hind feet while her young, hairless infant holds on (page 78). Flying lemurs are not closely related to the true lemurs of Madagascar but make up their own distinct order known as the Dermoptera, or "skin wings." They have the most extensive flight membranes of any mammalian glider, stretching from jaw to fingers to toes to the tip of the tail. Pushing off from a tree trunk (below), a female thrusts her limbs out to catch the air, revealing her young passenger (left). Unlike flying squirrels, which may leave their young in a tree cavity while foraging, colugo mothers generally carry their babies with them.

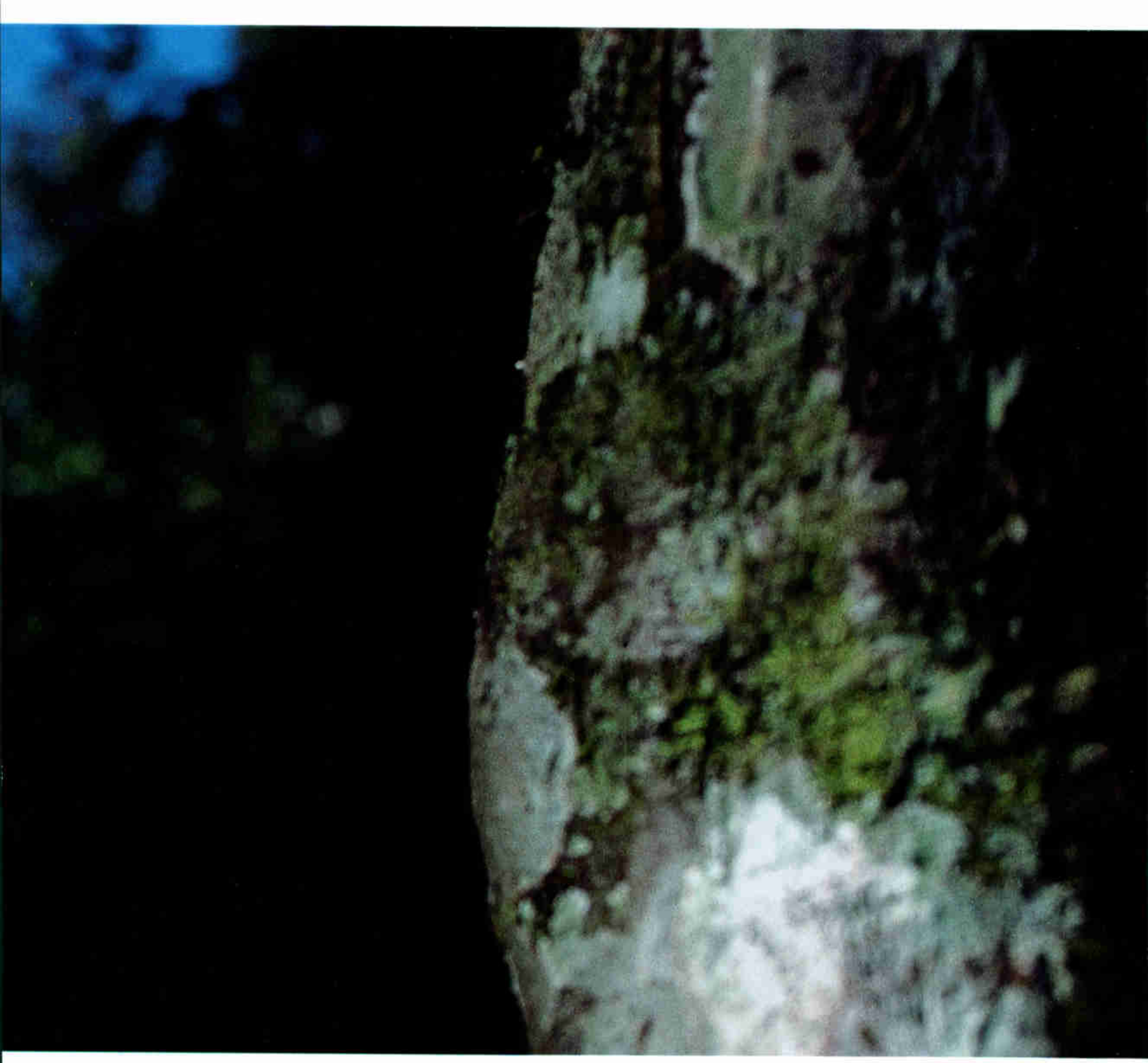




DRACO CORNUTUS (TOP)

DRACO VOLANS (OPPOSITE)

Draco lizards can leap from a tree trunk, loop around, and land farther down the same tree facing head up. Skin between elongated ribs on each side of their bodies is deployed like a super-fast umbrella when they leap (above), allowing them to make hundred-foot glides between trees. These most conspicuous of Borneo's gliders are active by day, foraging for ants and termites. Males defend their territories, displaying their prominent dewlaps (right) to opponents and potential mates alike. Rival males chase each other through the air, zipping from tree to tree like mini jet fighters.





GALEOPTERUS VARIEGATUS

Eyes ablaze with reflected light from my spotlight, a male flying lemur glides through the night as his kind have for millennia. His haunted look reminds me that if we don't do more to protect Borneo's disappearing rain forests, flying lemurs and all their fellow canopy dwellers will have nowhere left to glide. □



Covering more than two-thirds of the planet, the ocean was largely unknown until recently. Today, as improved technology delivers a tidal wave of information, scientists are trying to understand complex marine systems and interactions so we may become better stewards of our fragile biosphere.

NEW EYES ON THE OCEAN

BY JENNIFER ACKERMAN

Water swirls like wind-driven clouds around a seamount off Costa Rica. With "weather" of its own, the fluid realm of the ocean works with the atmosphere to regulate climate and make Earth habitable.

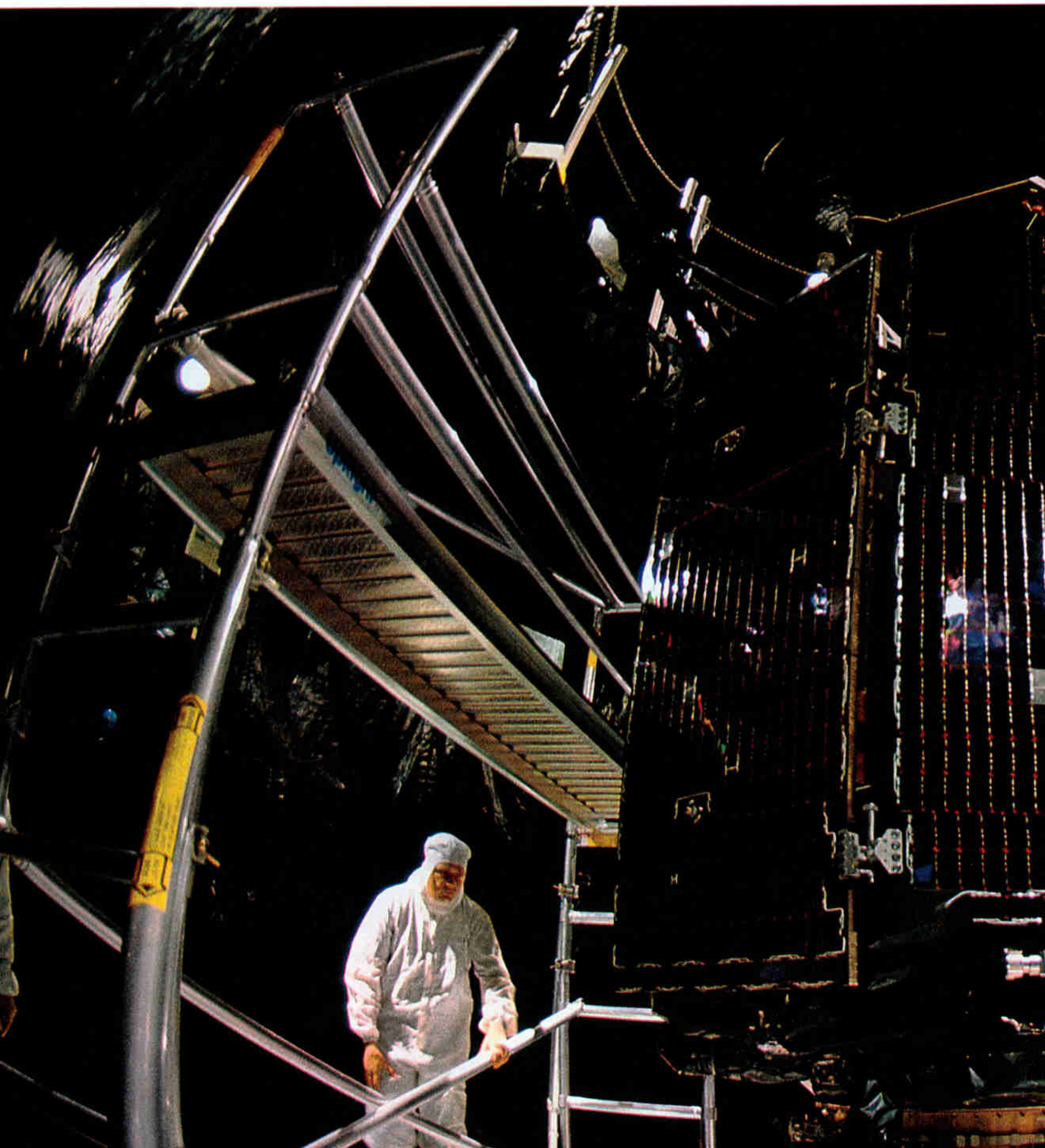
OCEANS

PHOTOGRAPHS BY CARY WOLINSKY

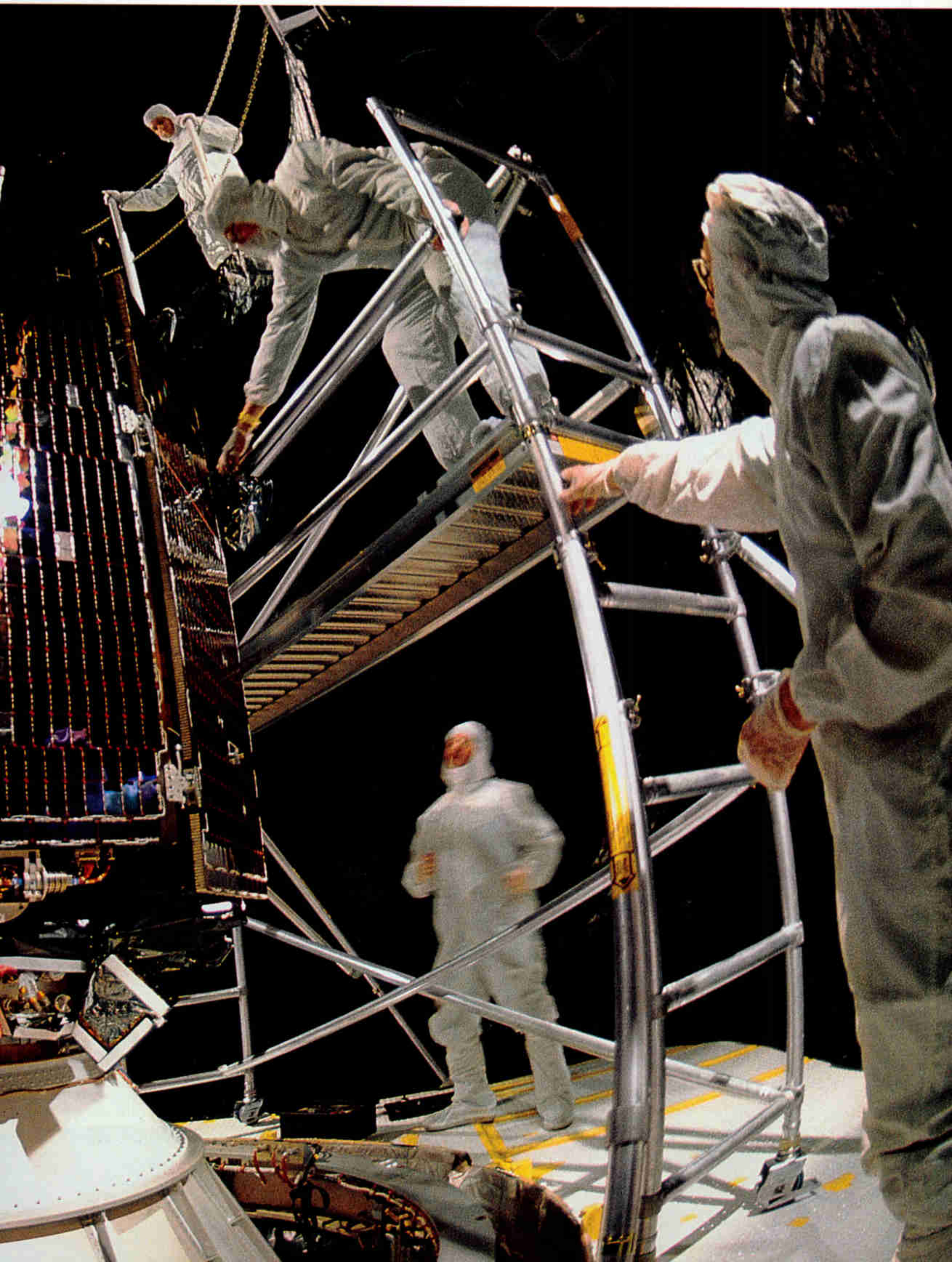
DAVID DOUBILET

WIDER HORIZONS

Success rides on the details that engineers double-check before the launch of NASA's Quik-SCAT spacecraft from Vandenberg Air Force Base, California. Now orbiting Earth every 101 minutes, the satellite measures wind speed and direction at the ocean's surface. "We need to



know that because, quite simply, winds drive the ocean," says principal investigator Michael Freilich. "They are responsible for the large-scale currents and influence the whole circulation of the upper ocean." In the past, readings could be taken only around ships and buoys.



PUTTING TOGETHER

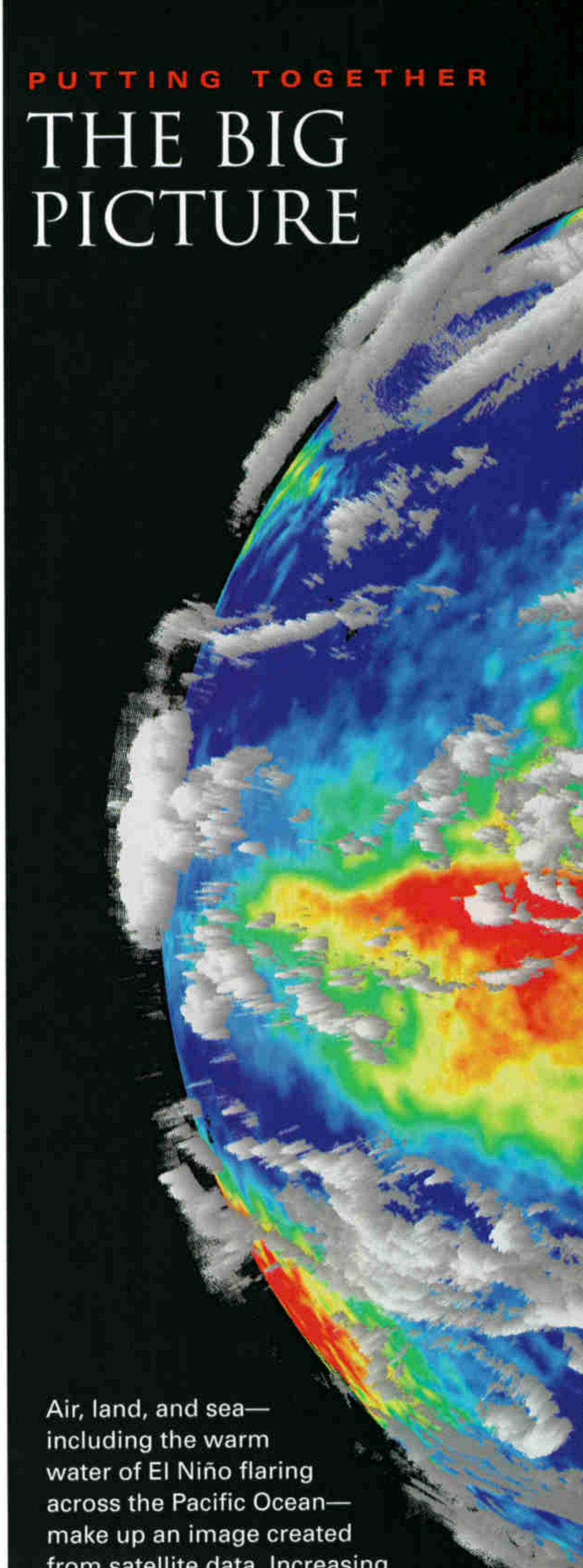
THE BIG PICTURE

AS THE R.V. *THOMAS G. THOMPSON* steams south from San Diego in the winter of 2000, those of us aboard have a personal demonstration of powerful ocean movement. Heavy swells, walls of gray water from a distant storm in the North Pacific, rock and toss the ship, making the greener among us miserable with seasickness. In the computer lab amidships a notice appears on the bulletin board: "Thought problem: What is the distance to the storm that generated this swell?" It's a good contemplative problem to take the mind off the heaving sea. But the real purpose of this cruise is to probe a more profound motion hidden beneath the endless hurrying forms of foamy waves and flying spray, a big, deep, mysterious movement of immense consequence.

The *Thompson*, a 274-foot research vessel owned by the United States Navy and operated by the University of Washington School of Oceanography, is headed south to trace the 24th parallel between North America and Hawaii. Its goal: to examine changes in the ocean since a research vessel last tracked this route 15 years earlier. We have aboard Capt. F. Gray Drewry and 19 crew members and 22 members of a science team, including 15 graduate students. Leading the cruise is chief scientist Steve Riser, a professor of physical oceanography at the University of Washington and a veteran of sea cruises all over the world.

On the deck of the *Thompson* waits an impressive suite of oceanographic instruments, all strapped and secured against the roll and pitch of the ship. The *Thompson*'s main deck is given over to spacious labs humming and buzzing with banks of computers and electronic devices to measure the velocity of currents, read the surface temperature of the sea, fix the speed of wind, probe the seafloor with sound waves, and display in real time the special characteristics of a column of seawater.

Some of the scientists hover about the computer screens, commenting on the sea's patterns of heat and salt; others are in the laboratories analyzing water samples. The tools and techniques of these scientists may diverge, but their mission is one: to read the



Air, land, and sea—including the warm water of El Niño flaring across the Pacific Ocean—make up an image created from satellite data. Increasing amounts of information from all three realms are helping scientists study how they interconnect to form a finely balanced system.

IMAGE BY RUDOLF B. HUSAR, WASHINGTON UNIVERSITY, ST. LOUIS, MISSOURI; LAND LAYER FROM THE SEAWIFS PROJECT; FIRE MAPS FROM EUROPEAN SPACE AGENCY; SEA-SURFACE TEMPERATURE FROM THE VISUALIZATION LABORATORY, NAVAL OCEANOGRAPHIC OFFICE, U.S. NAVY; CLOUD LAYER FROM SSEC, UNIVERSITY OF WISCONSIN, MADISON

movements of water masses traveling around the planet, season to season, decade to decade, century to century and to plumb the profound effects of these, the large-scale motions of the biggest thing on Earth.

ROOTED AS WE ARE in our firmament of soil, of continent, countryside, city, we easily forget the liquid nature of the planet. Ours is an ocean world, 70 percent water. Over the past few centuries the surface of the sea, its length and breadth, has largely been explored, its regions mapped and named. But the ocean's third dimension, the unseen world of the deeps, and its fourth, its movements over time, have been difficult to delineate—seas of darkness.

That is beginning to change. With the help of an extraordinary set of new technological "eyes," oceanographers have begun to pierce the ocean's opacity, to see beneath its surface and follow its motions through time. Some of these eyes are narrow focus, measuring molecules in a small slug of water to "fingerprint" currents. Others are smart little torpedo-like floats, electronic biographers of seawater that wander the ocean's paths. Still others are delivering a bird's-eye perspective, viewing aloft from satellites the whole bulging blue lens of the global ocean, bouncing radar beams off the sea surface to gauge changes. Together these eyes are revealing a physical ocean more complex and changeable than we ever imagined, more like a weather system than a geological one, complete with turbulence, fronts, and strange abyssal storms.

From land, from the threshold of dunes or tidal flats, the sea is a placid blue margin. But out there in the middle of it, the sea is something else. The ancient Greeks believed that the ocean flowed around the Earth and into eternity. On the great Pacific, where even as grand a vessel as the *Thompson* seems a mere duckling, one can see why. Day after day the ship sails toward an endlessly receding horizon. Sometimes we are joined for a short leg of our journey by a storm-petrel, fleet and swallow-like, or a pod of porpoises schooling up fish. But for the most part we are floating alone in a vast "sweet mystery," as Herman Melville called it, animated by "gently awful stirrings."

From the deck of the research vessel, looking down on the water, sometimes slate colored, sometimes a troubled green, I try to imagine the sea's journeys. There is, of course, no clear starting point for its travels, no single faucet. Though we've labeled the ocean as if it consists of discrete entities—Indian, Pacific, Atlantic—its waters are one, gathered in a single highly contorted basin.

From the beginning, sun, winds, and the spinning of the Earth have conspired to keep the ocean in motion and put a twist in the direction of its currents. Swirled by the planet's winds and rotational forces and confined by its landmasses, the water spins to the right, or clockwise, in the northern oceans and to the left, or counterclockwise, in the southern. Easterly trade winds near the Equator push water to the west, while westerlies in the midlatitudes push it to the east. Together, wind and spin



create huge circulating gyres (from the Greek *gyros*, meaning "circle") made up of currents. Because of the planet's rotation and spherical nature, the currents are more intense in the western part of the gyres, creating such narrow, swift western-boundary currents as the Gulf Stream, which rolls from the Straits of Florida out toward the Azores in the Atlantic, and the Kuroshio, the indigo blue Pacific current that runs up the continental shelf off eastern Asia.

The sweep of these giant spinning gyres is intimately linked with a longer, deeper water journey. The main act in this drama of global ocean circulation occurs in the northern polar regions of the Atlantic, where water cooled by ice becomes so heavy it plunges downward, displacing warmer water below. This cold, heavy young water, joined by dense salt water flowing out from the Mediterranean, travels southward at great depths, eventually spreading around the Antarctic circumpolar regions. From there it mixes with warmer water in the tropical regions of the Indian and Pacific and reenters the Atlantic, where it rises and flows back northward along the surface as older water all the way to Greenland and the Labrador Sea, thence to chill and become cold, heavy young water again, starting the cycle anew. The trip can take a thousand years to complete.

This grand whole-ocean voyage—called the thermohaline circulation because it is driven by differences in the heat and salt content of seawater—is enormously more complicated than this picture would suggest, and scientists are struggling to grasp its details. But most oceanographers *(Continued on page 99)*



SERENDIPITOUS SCIENCE

An unlikely drifter, this hockey glove was one of 34,000 that spilled from a cargo ship in a 1994 storm. About 500 hockey items have since washed up on beaches between Oregon and Alaska. Computer models of their probable paths are teaching scientists about the dynamics of currents.

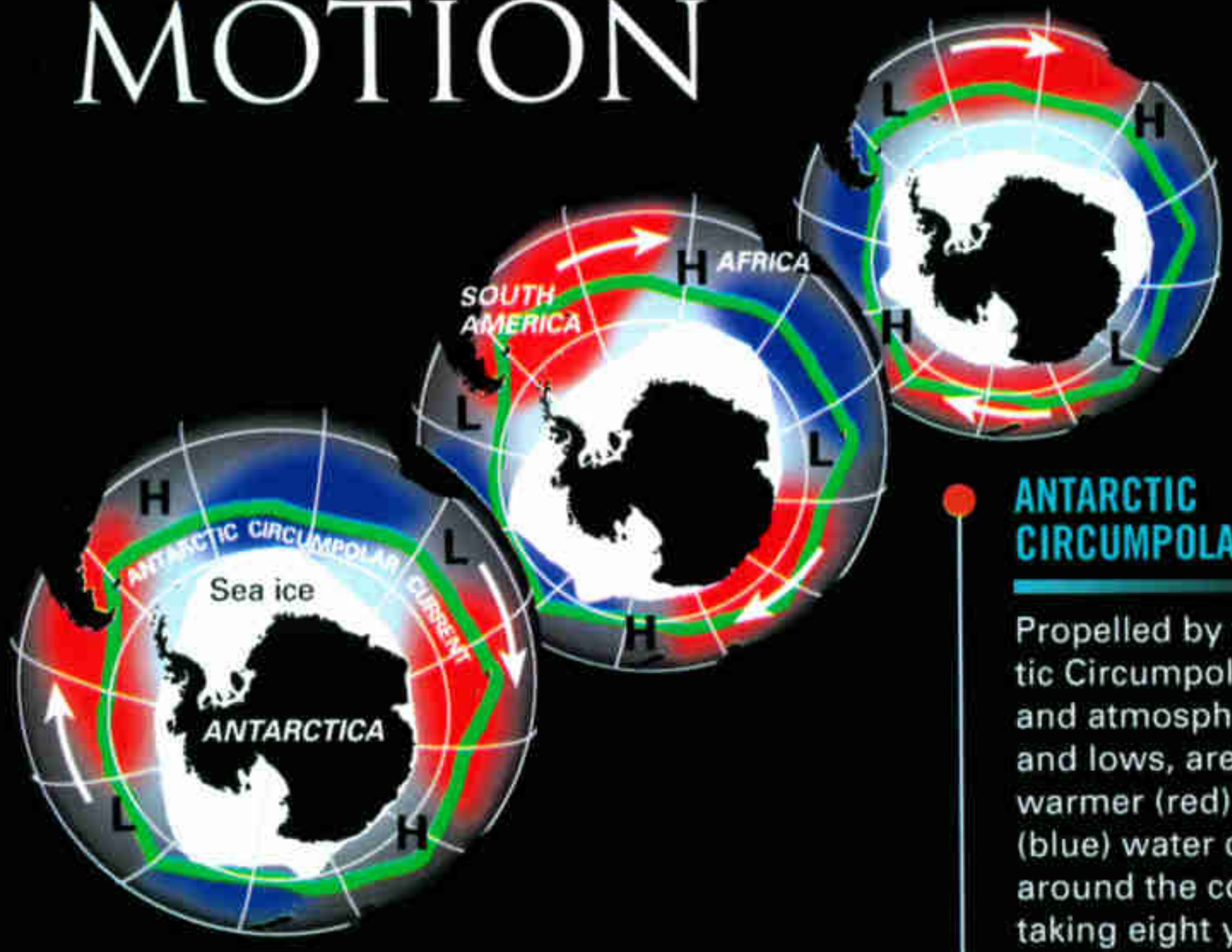
SOURCES: JIM INGRAHAM, NATIONAL MARINE FISHERIES SERVICE, NOAA; CURTIS EBBESMEYER, EVANS-HAMILTON

NG MAPS



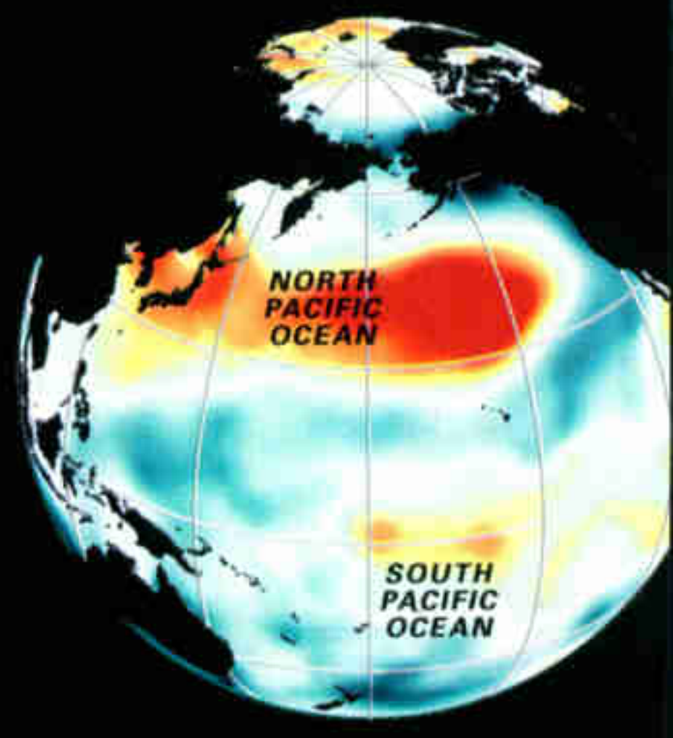
THE RHYTHMS OF

AN OCEAN IN MOTION



Constantly interacting with the atmosphere, the ocean affects climate and thus seasonal weather. "The ocean is the key to understanding climate changes," says Walter Munk, a researcher at Scripps Institution of Oceanography in California. "If you don't get the ocean right, you're not going to get the atmosphere right."

Satellites and floating sensors have helped scientists map the ocean's circulation. In surface currents (red arrows, at right) water warmed by the tropical sun carries heat to higher latitudes. Becoming saltier by evaporation, the water ultimately reaches the North Atlantic Ocean, where it cools and sinks. Flowing in deep currents (blue arrows), it helps cool the tropics as it upwells and starts the cycle again. More easily observed are shifts in sea-surface temperature, such as occur during El Niño, that affect local weather and at times global climate patterns.

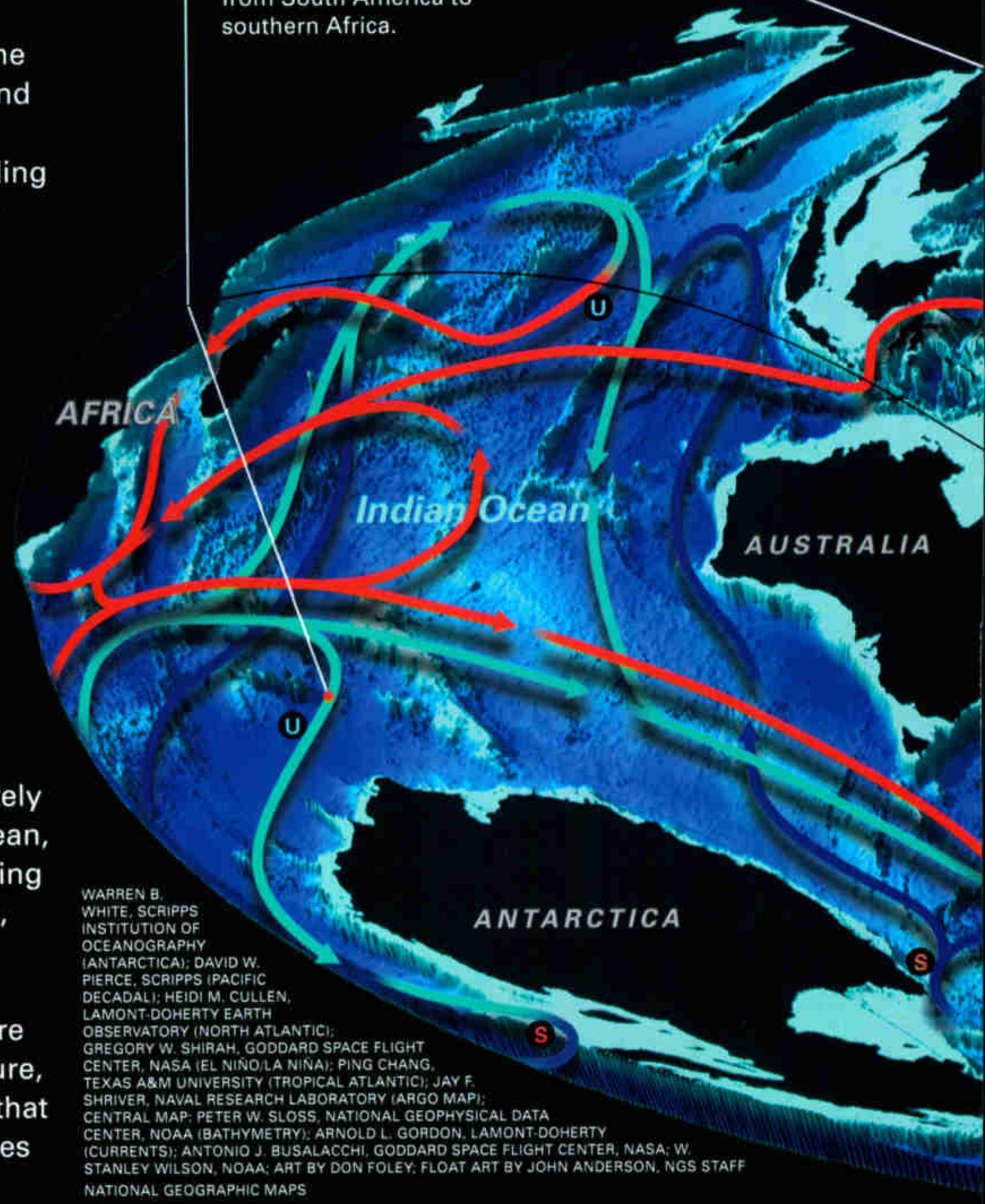


PACIFIC DECADAL OSCILLATION

This long-term change in sea-surface temperatures seems to have two phases. From about 1977 to 1997 temperatures in the middle and western part of the North Pacific Ocean were cooler than average, while waters off

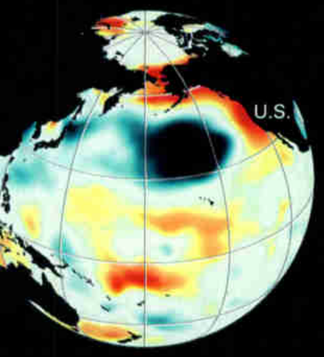
ANTARCTIC CIRCUMPOLAR WAVE

Propelled by the Antarctic Circumpolar Current and atmospheric highs and lows, areas of warmer (red) and colder (blue) water circulate around the continent, taking eight years to complete the journey. During three of those years, warm water moves from South America to southern Africa.



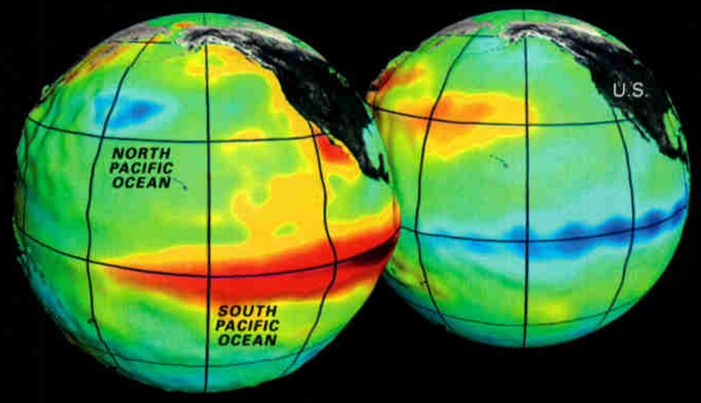
WARREN B. WHITE, SCRIPPS INSTITUTION OF OCEANOGRAPHY (ANTARCTICA); DAVID W. PIERCE, SCRIPPS (PACIFIC DECADAL); HEIDI M. CULLEN, LAMONT-DOHERTY EARTH OBSERVATORY (NORTH ATLANTIC); GREGORY W. SHIRAH, GODDARD SPACE FLIGHT CENTER, NASA (EL NIÑO/LA NIÑA); PING CHANG, TEXAS A&M UNIVERSITY (TROPICAL ATLANTIC); JAY F. SHRIVER, NAVAL RESEARCH LABORATORY (ARGO MAP); CENTRAL MAP: PETER W. SLOSS, NATIONAL GEOPHYSICAL DATA CENTER, NOAA (BATHYMETRY); ARNOLD L. GORDON, LAMONT-DOHERTY (CURRENTS); ANTONIO J. BUSALACCHI, GODDARD SPACE FLIGHT CENTER, NASA; W. STANLEY WILSON, NOAA; ART BY DON FOLEY; FLOAT ART BY JOHN ANDERSON, NGS STAFF

NATIONAL GEOGRAPHIC MAPS



the western U.S. were warmer (above).

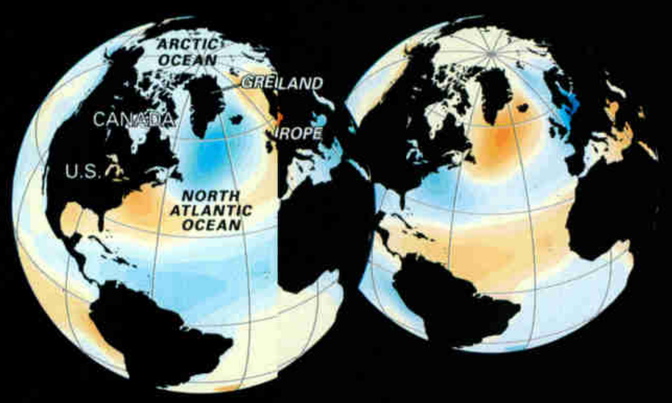
At the end of the 1990s, however, temperatures flip-flopped, perhaps signaling a return to the conditions that were last prevalent between 1947 and 1976 (above left).



EL NIÑO AND LA NIÑA

Every three to seven years an area in the Pacific Ocean one and a half times the size of the continental U.S. becomes warmer than normal by as much as 10°F (red area, above). Called El Niño, this phenomenon last occurred in 1997-98, when it was exceptionally strong and disrupted climate around the world.

La Niña, the cold-water counterpart (blue area, above) that often follows such a strong El Niño, is now on the wane.

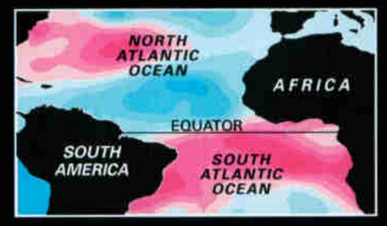


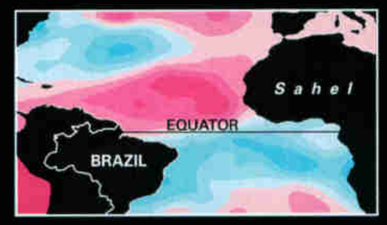
NORTH ATLANTIC OSCILLATION

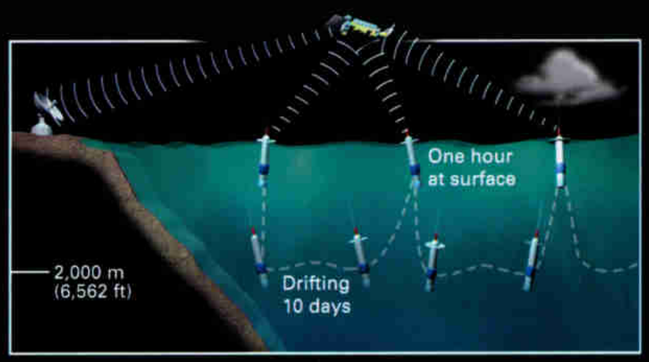
With a puzzling tempo, the seesawing behavior of atmospheric pressure over the Arctic and the subtropical North Atlantic Ocean determines sea-surface temperature and winter weather in the area. When the pressure is lower than normal over the Arctic, the eastern U.S. and northwestern Europe experience mild winters (above left, yellow areas). This phase has now lasted for 30 years. In the opposite phase, winters are mild in eastern Canada and Greenland.

TROPICAL ATLANTIC VARIABILITY

Variations in sea-surface temperature in the Atlantic Ocean affect precipitation patterns in parts of South America and Africa. When water north of the Equator is colder (blue, top right) than water to the south (red), northeast Brazil receives higher than average rainfall, and the Sahel experiences drought. Reversals in sea-surface temperature (bottom right) bring opposite precipitation patterns.



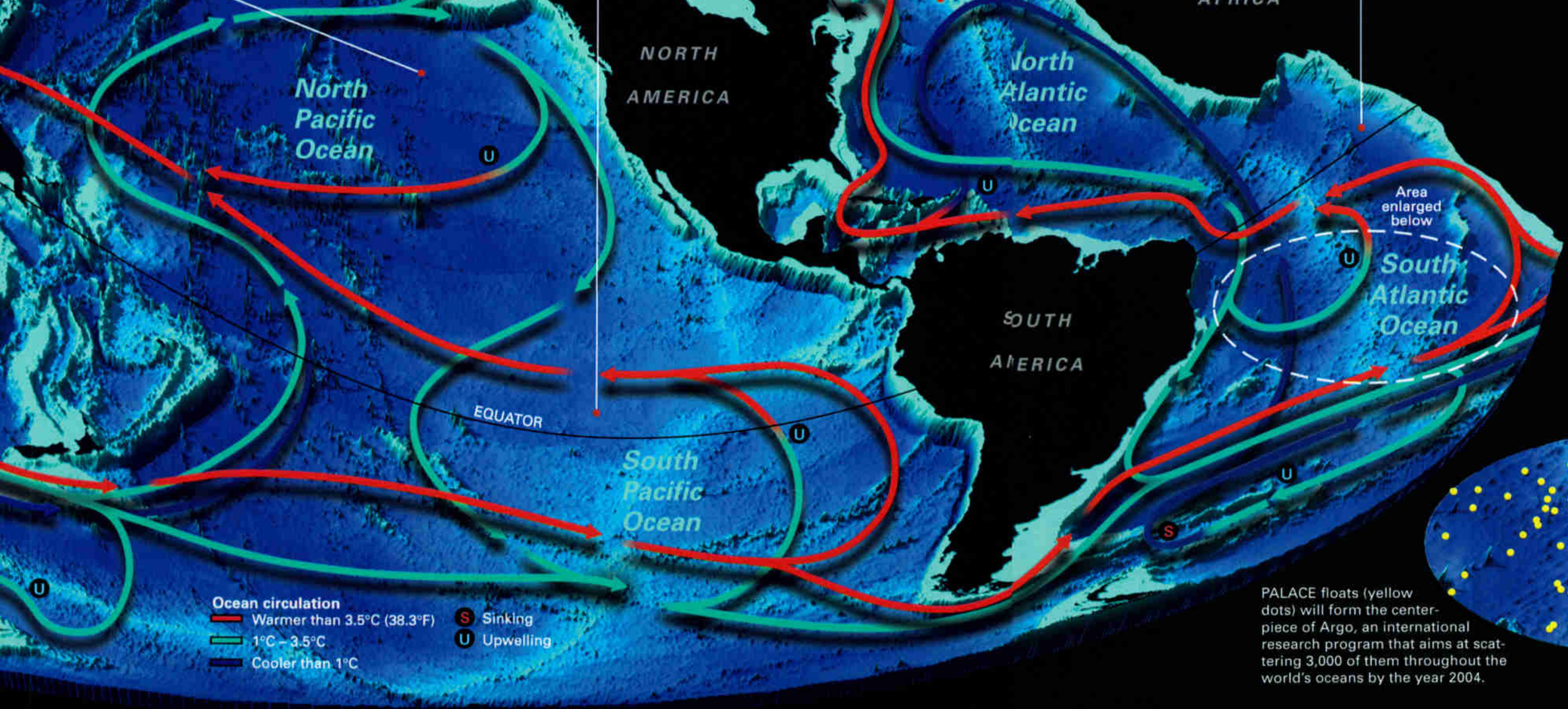


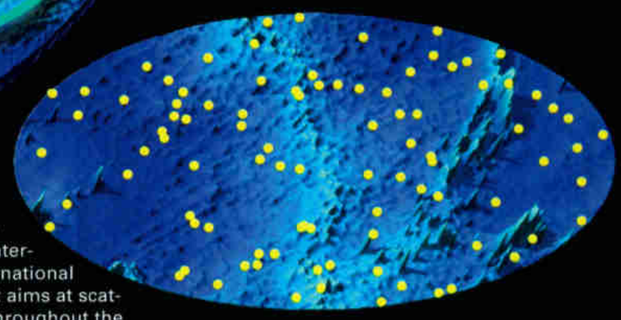


RESEARCH REVOLUTION

An array of new autonomous ocean-going instruments gathers data much more efficiently than was ever possible from ships. One device, a PALACE float, bobs in a timed cycle as it drifts. At its apex it sends information about salinity, temperature, and currents to a satellite, which forwards everything to land-based scientists.







PALACE floats (yellow dots) will form the centerpiece of Argo, an international research program that aims at scattering 3,000 of them throughout the world's oceans by the year 2004.

EUROPE

COLD WEATHER AHEAD?

At the same latitude as Newfoundland and northern Mongolia, gardens in Cornwall, England, can grow plants from places much closer to the Equator thanks to the warming influence of the Gulf Stream. With 800 times the volume of the Amazon River, the current transports solar heat from the Caribbean to Europe.

John Nelson, retired director of Heligan Gardens, displays a copy of the first chart of the Gulf Stream (below). Benjamin Franklin had the original printed in about 1770, hoping mail ships would catch the speedy flow on their trips from America to England.

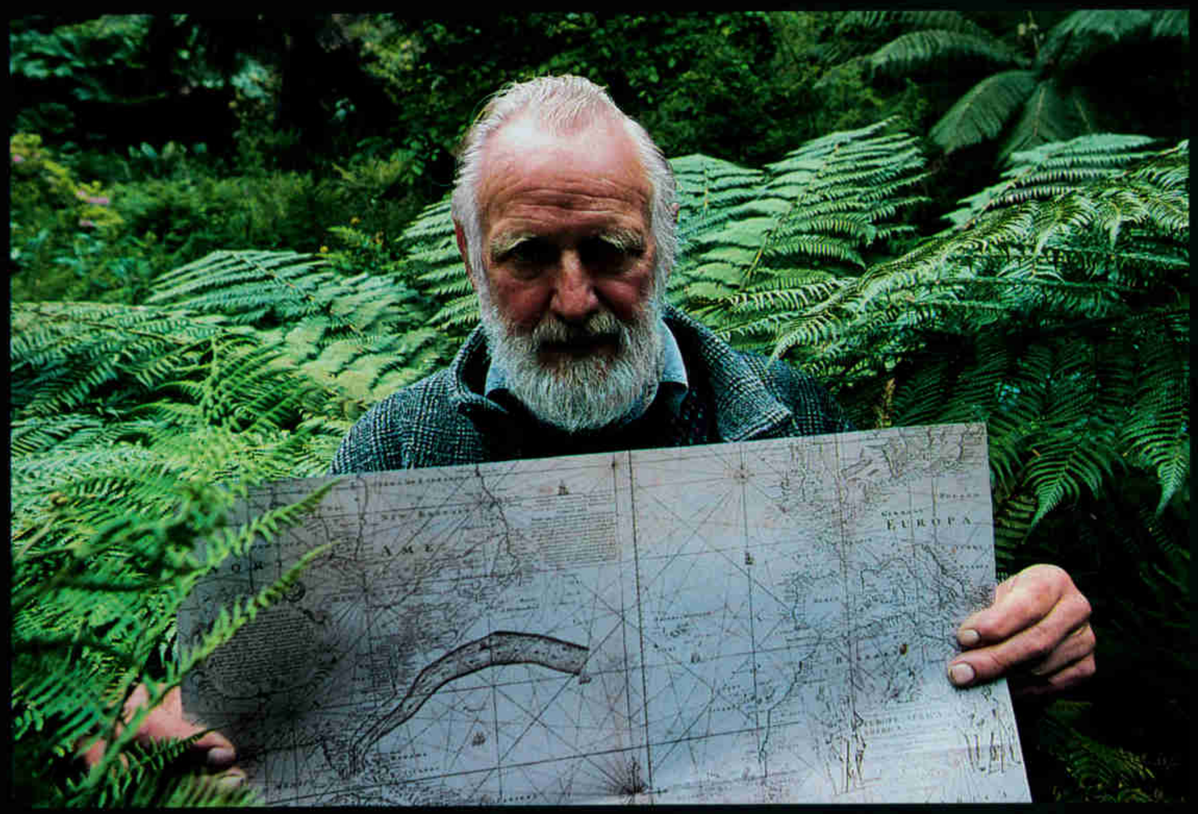
Ferns from Australia, planted in the late 1800s, surround Nelson. In the same valley a gardener checks on a giant subtropical gunnera (left). Native greenery fleshes out a sculpted face nearby (far right).



DAVID HASTILOW

"We do get a freak storm every now and again," says Nelson, explaining the dusting of snow in February 1994 (above). "But it never lasts more than a few hours."

Some scientists think a killer chill may be on the way though. If carbon dioxide in the atmosphere continues to increase, warming could cause melting of polar ice caps and increase rainfall. The infusion of fresh water would likely disrupt the current, and long Siberian winters could quickly seize Europe.



(Continued from page 93) agree on its broad pattern—and on its immense significance.

"This global circulation has two life-giving effects," explains Peter Rhines, an oceanographer at the University of Washington. "First, its rising branches bring up deep nutrients, which make possible the food chain of the sea. Second, it smooths out temperature differences by transporting tropical heat to the Poles."

The ocean acts as a huge reservoir of heat absorbed in the tropics, and its currents distribute that heat over thousands of miles. The Gulf Stream and its extension, the North Atlantic Current, bring a gentling influence to the lands lying downstream; without it northern Europe



would be a gray and icy land. Slight changes in the temperatures of currents can influence air temperatures and weather patterns worldwide. Perhaps the best known example of this is El Niño, the periodic warming of Pacific waters that brings heat and cold, drought and flood in accordance with its varying strength and warmth. But lately oceanographers have found other, subtler climatic effects raised from currents, which point to the tight coupling of ocean and atmosphere. "So closely bound are sea and air," says Steve Riser, "that we cannot seriously attempt long-term climate forecasts without knowing ocean circulation."

Fifty years ago scientists believed the great system of ocean circulation stable and changeless; now things look otherwise. Not only do the ocean's so-called permanent currents seem to vary at nearly every scale of time and space, but the fundamental circulation structure may be shifting as a result of global warming, with possibly disastrous consequences.

The key to understanding the puzzle of ocean circulation and how it might be changing lies in its subtle details—how seawater moves from one part of the planet to another, how it travels from the surface down to the interior and rises again from the depths, and the nature of the tremendously important events occurring at the thin interface between the ocean of water and the ocean of air.

But just how does one fathom what is huge, mostly hidden from sight, and ever in motion?

ON A MOONLESS NIGHT the *Thompson* moves in a narrow tunnel, bottomed by ultramarine foam visible only in the wake of the ship, walled by a Bible black darkness that recalls the darkness of an earlier age. It has been over a millennium since the Polynesians sailed their open canoes across the Pacific, using stars, signposts of the sea, and the strange, perilous liquid paths of currents to move from one island to the next. It has been 400 years since Galileo's telescope opened the night sky, resolving the Milky Way into swarms of individual stars.

Today we know more about the topographies of Mars and Venus than about most of Earth's oceanic areas. Knowledge of the sea has lagged behind that of land and even space, in large part because of what oceanographer Carl Wunsch describes as the "brute difficulty" of observing the oceans. As an environment for study, the sea is as hostile to instruments as the black reaches of interplanetary space, and in some ways more difficult to penetrate. Its enormous pressures and nasty habit of corrosive gnawing on all metal structures challenge even the most robust instruments. The winds and waves of the open sea stymie the efforts of the research ship, often limiting its working days to one in three. Most important, says Wunsch, a professor of physical oceanography at MIT, "seawater itself is almost opaque to our conventional ways of seeing"; its fluid properties "short out" light waves, making it, indeed, a sea of darkness.

For centuries oceanographers have snatched clues to currents where they could. Early ideas about the speed and direction of currents often came from stray objects that floated and drifted for years—sealed bottles, rafts, the gloomy, waterlogged hulks of abandoned ships called derelicts.

TIMELESS JOURNEY

The patterns of waves in the Pacific Ocean help guide the *Hokule'a,* a traditional voyaging canoe, on its 14,000-mile round-trip between Hawaii and Easter Island. "Our ancestors had to know the ocean intimately," says navigator Nainoa Thompson. "Mistakes could be fatal." An early stick chart from Micronesia (bottom) shows the waves and currents around islands, represented by shells.

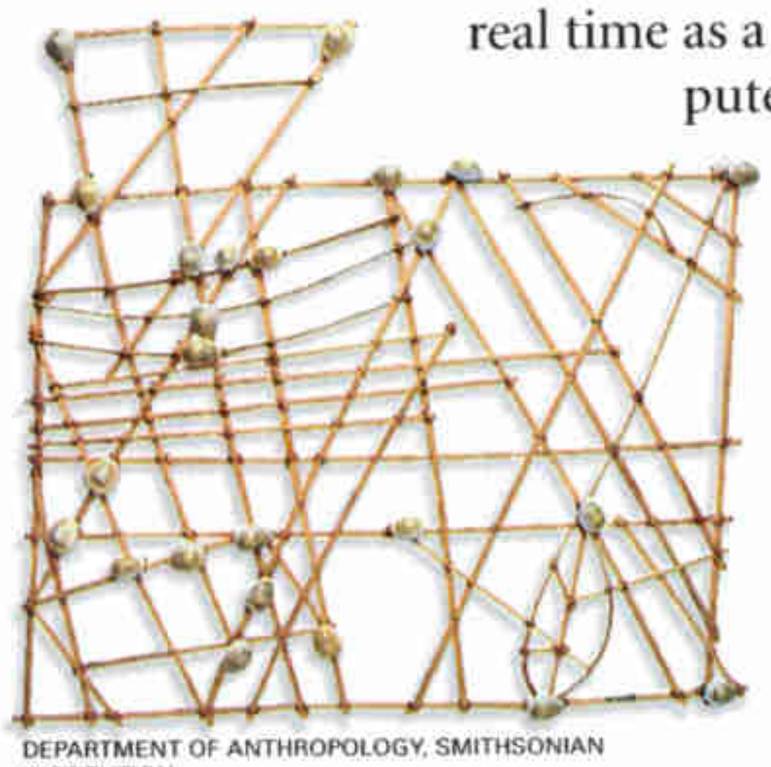


These days a host of ingenious instruments delivers intriguing news of the origins and routes of water. Perhaps the single most useful instrument for physical oceanographers is the CTD (conductivity-temperature-depth) recorder, which measures the salinity and temperature of a particular mass of seawater at various depths. Identifying these properties is key to determining how, where, and when currents move.

Seawater takes the form of these masses, or layers, each with qualities and characteristics peculiar to its own history, differing in temperature, salinity, oxygen content, and density. Distinct masses of different densities are stacked one on top of the other, like the layers of the Grand Canyon but in fluid motion. "Give me the profile of temperature and salt in a water mass," says Steve Riser, "and I can usually tell you what part of the ocean it came from." The temperature and salt content of a parcel of Atlantic seawater, for instance, vary depending on where the water originated. High salt content suggests origins in the Mediterranean. Lower salt content suggests origins in the polar seas, which are constantly diluted by snow and melting ice.

Every hundred miles or so the *Thompson* throttles back its engines and holds its place at a station, a highly precise location in the blank and shifting blue determined by the network of satellites known as the global positioning system (GPS). Our path transects the center of the northern Pacific gyre, a good, quiet place to look for change in the ocean.

Over the starboard side goes the CTD instrument, a cage housing an array of measuring devices and a carousel of bottles to take water samples at various depths. The cage is lowered by winch to depths of 1,000 to 2,500 meters (3,280 to 8,200 feet). As it descends into the blue darkness, the CTD takes a steady stream of measurements, 40 samples a second, which, in a feat of technical wizardry, appear in real time as a graph of snaking lines on a computer console in the lab of the ship: blue for temperature, red for salinity, green for density, purple for oxygen, all plotted against depth—or, more precisely, pressure. In the emerging pattern of these wriggling lines is written the composition and character of the water mass. As the cage rises, the scientists at



DEPARTMENT OF ANTHROPOLOGY, SMITHSONIAN INSTITUTION



the computer console trigger a set of 24 water bottles to collect samples at various depths. These will be analyzed for the presence of tracers—oxygen and chlorofluorocarbons—that will help date the water, showing the time it was last in contact with the atmosphere and, hence, how old it is.

The 26 such casts we take over the course of this cruise will help the oceanographers aboard determine the makeup of a uniform mass of water known as mode water, now flowing south over the 24th parallel. What are its properties? What is causing it to behave the way it does? Mode water may affect storm tracks in the Pacific and the timing of El Niños. It may also reveal long-term climate change. A similar water mass at the same latitude in the Atlantic Ocean is warmer by one degree than it was 30 years ago. The sign of a natural fluctuation? Or perhaps news of global warming?

ON THE WALL of my study is a map showing the expedition tracks of research ships over the world's oceans during the past three decades. Parts of the map—the waters near the coasts of North America, the areas around Hawaii and the Azores—are so dense with tracks they're solid black; other sections are nicely hatched with orderly grids. But great swaths of ocean in the South Pacific and the Southern Ocean are crisscrossed only sparsely or not at all and look just as I imagine the desert blanks of the Gobi or Sahara look at night from space.

Some of the tracks on this map were laid in the 1990s during the World Ocean Circulation

Experiment, or WOCE, the most ambitious scientific program ever attempted in the world's oceans. Scientists from 30 countries conducted intense sea operations, including more than 500 research cruises, in an effort to get a picture of global ocean circulation.

"The goal, ultimately, was to help build good oceanographic data into computer models designed to depict climate and climate change," says Lynne Talley, a physical oceanographer at the Scripps Institution of Oceanography in La Jolla, California, who participated in WOCE from its beginnings. Over eight years WOCE measured chemical tracers in the ocean and collected 20,000 profiles of ocean temperature and salinity, which have helped refine models used for long-term weather forecasts.

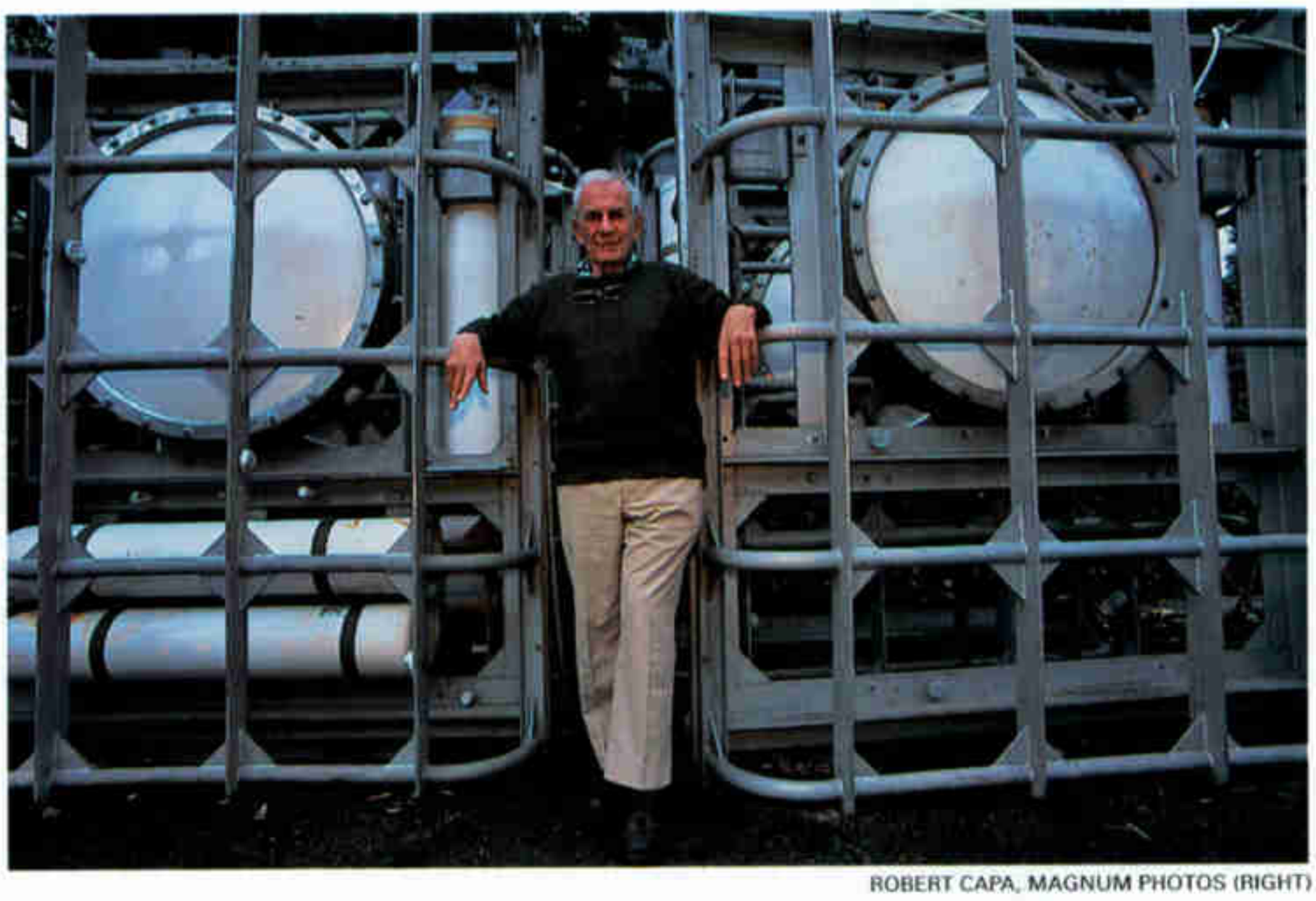
Robert Pickart went to sea on WOCE-related cruises eight times in three years, filling in some of the holes in that map of sea tracks. A boyish, energetic oceanographer at the Woods Hole Oceanographic Institution in Woods Hole, Massachusetts, and the father of five small children, Pickart led a research cruise in the winter of 1997 to the Labrador Sea. A harsh, remote area in the far northwest corner of the North Atlantic, the Labrador Sea is one of the few places where conditions are right to form the young, cold water that helps drive global ocean circulation. Here, when strong westerly winter winds blow bitterly cold air from Canada, the chilled surface waters sink in a process known as deep convection, sending cold water masses through the deeps and hence to other oceans.

The very conditions that create this phenomenon—subfreezing temperatures, frequent storms, winds gusting to 50 knots—make its observation extremely difficult. "No one wants to go up there and get pounded," says Pickart.

But go Pickart did. For 47 days he and his team on the R.V. *Knorr* zigzagged the frigid waters of the Labrador Sea, dodging giant ice chunks known as growlers and smaller bergy bits, looking for places where convection might be occurring.

Each day Pickart e-mailed his children, at one point recounting the story of a young snowy owl that took refuge in the bow of the ship during a severe storm and the crew's heroic efforts to save it. "The sun shone only two days during the whole expedition," Pickart recalls. "Most days it snowed constantly. Sea spray froze quickly on the ship's decks, bulkheads, and bulwarks, building into walls of ice ten inches thick. The crew members had to chip away the ice with mallets every few days so the *Knorr* wouldn't become dangerously top-heavy."

Pickart and other scientists suspected that deep convection was taking place at the edge of the continental shelf, moving cold water masses directly into the deep western-boundary current—a cold limb of the thermohaline circulation. If they were right, the whole downstream system of currents would likely feel the effects of climatic change in the Labrador Sea much more quickly than scientists had previously suspected. Tethered to the ship with ropes in driving snow, Pickart and his team somehow lowered their CTD and other instruments into an icy, roiling sea and got the measurements they needed to prove their theory.



ROBERT CAPA, MAGNUM PHOTOS (RIGHT)

OCEANOGRAPHY has always suffered from a plague of undersampling, in part because of the great difficulty and expense of studying the oceans in remote locations or under stormy conditions but also because of the limitations of the tools. Twenty-five years ago most of what was known about the oceans had been gathered

painstakingly by research vessels like the *Thompson* and the *Knorr*. The problem is this: Oceans are big, deep, and moving. Ships are slow, bound to the surface, and narrow in their tracks. "A few ships chasing around the sea can't see things that shift in time and space," explains Walter Munk of the Scripps Institution. At best, ship research can create only piecemeal images, scattered and hard to link up.

On the wall of my study hangs another map, a brilliantly colored image of the whole global ocean, showing in tones of yellow, orange, red, blue, green, and purple the slight mounds and depressions of the sea surface. The image was created with data from the satellite TOPEX/Poseidon. A project shepherded into being by Carl Wunsch, TOPEX/Poseidon has been in orbit since 1992, circling Earth 4,700 times a year, mapping the subtle, fluctuating hills and valleys of the ocean's surface.

One thinks of the vast ocean as flat, but it actually dips and bulges, in part because of converging and diverging currents that cause water to pile up or move apart. So sensitive are the radar altimeters of TOPEX/Poseidon that even from its height 830 miles above the planet, it can detect elevation to within an inch or so across hundreds of miles of ocean surface. Because the satellite measures along the same track every ten days, scientists can see how the ocean changes over time. From the resulting maps they can calculate the speed and direction of surface currents.

"With satellites we can take a steady stream of measurements nearly everywhere at once," says Wunsch. "A sampling of data that would take a research ship years to complete a satellite can do in days." Ocean-observing satellites now circling Earth can measure sea-surface temperature and height, ocean winds, and chlorophyll, an indication of biological activity on the sea surface.

Satellite images reveal features of surface currents, including fluctuations in the Gulf Stream and the birth, evolution, and death of eddies, vortices of water that spin off major currents, often creating islandlike ecosystems for marine organisms. Some eddies are enormous, more than a hundred miles in diameter and thousands of feet deep and can last for years before dissipating; when they sweep into an area, they can change the weather.

But satellites see *(Continued on page 108)*

WAVE ACTION IN WAR AND PEACE

Amphibious landings of Allied troops during World War II, including the D day invasion of Normandy (below), were possible because scientists such as Walter Munk learned how to predict wave conditions. Now at Scripps, Munk (left) tests global warming theories by documenting ocean temperatures. Sound from the underwater speakers travels faster through warm water than through cold.



AFRICA

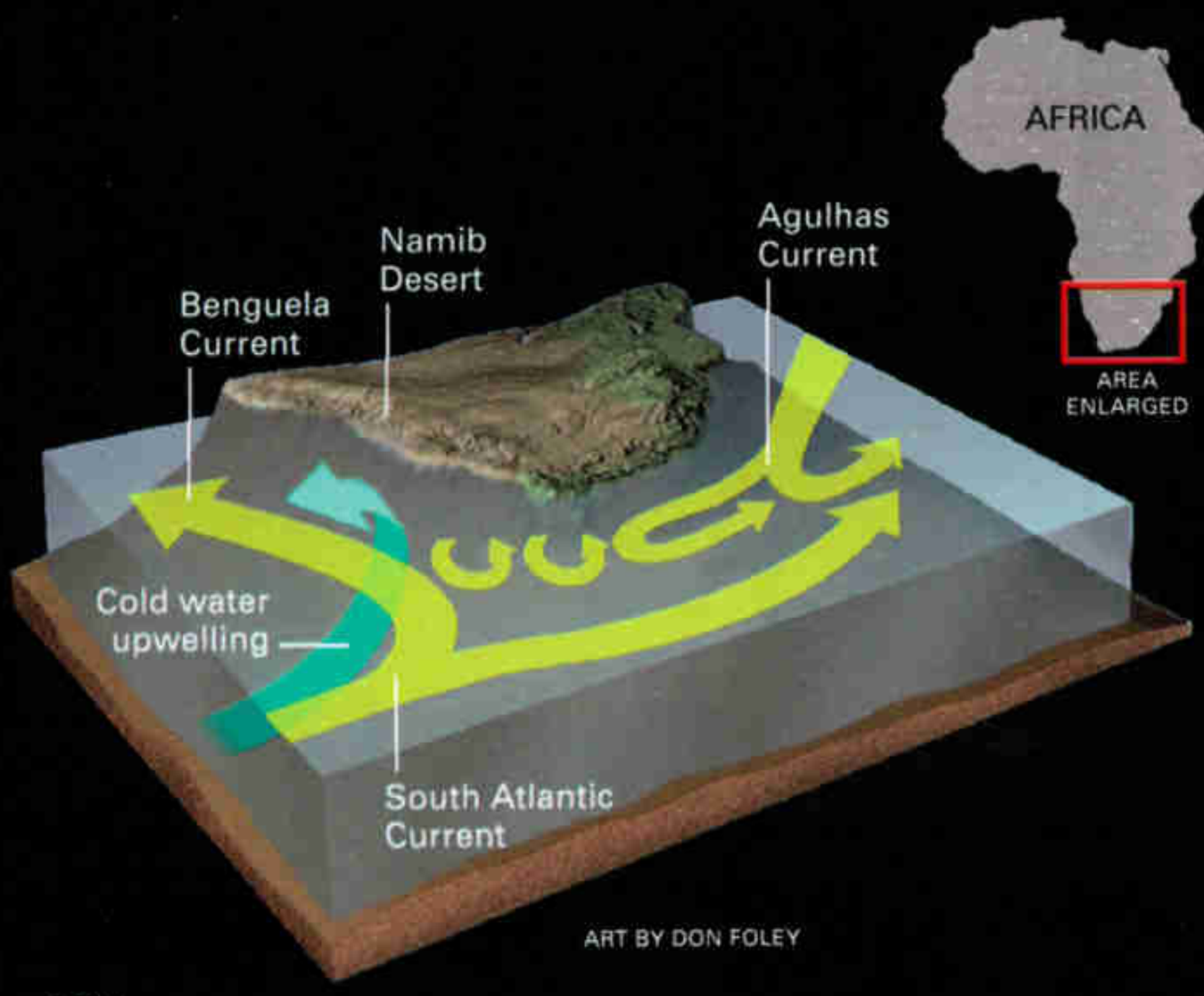
DESERT FOG

For the past ten million years coastal waters have helped shape the Namib Desert, one of Earth's driest areas. Between the northward flowing Benguela Current and the shore of southern Africa, cold water wells up from the deep ocean (diagram, bottom). This water cools the moisture-laden air, preventing it from rising to make rain clouds. Instead, fog forms.

Floating over the ocean, the fog ends at the desert's edge where it runs into dry, sun-warmed air. As evening cools the desert, the fog moves inland as far as 75 miles.

At the start of a new day the fog burns off in patches over the desert (above) and is usually gone before noon. "During the day we'll see the fogbank lurking offshore and say, Oh, it's going to be a thick one tonight," says Peter Ward, a safari organizer.





ART BY DON FOLEY





Desert creatures small and large have adapted to these conditions. Fog-basking beetles, called tok-tokkies (opposite), trek to the top of a dune at dawn. Holding their rears high, they wait for fog to condense on their bodies. The resulting water then rolls down to their mouths. Elephants migrate between oases. They start grazing early in the morning, when plants are still wet with dew.

IN HURRICANE ALLEY

HOW STRONG WILL THE WINDS GET?



COMPUTER SIMULATION: ISAAC GINIS, UNIVERSITY OF RHODE ISLAND

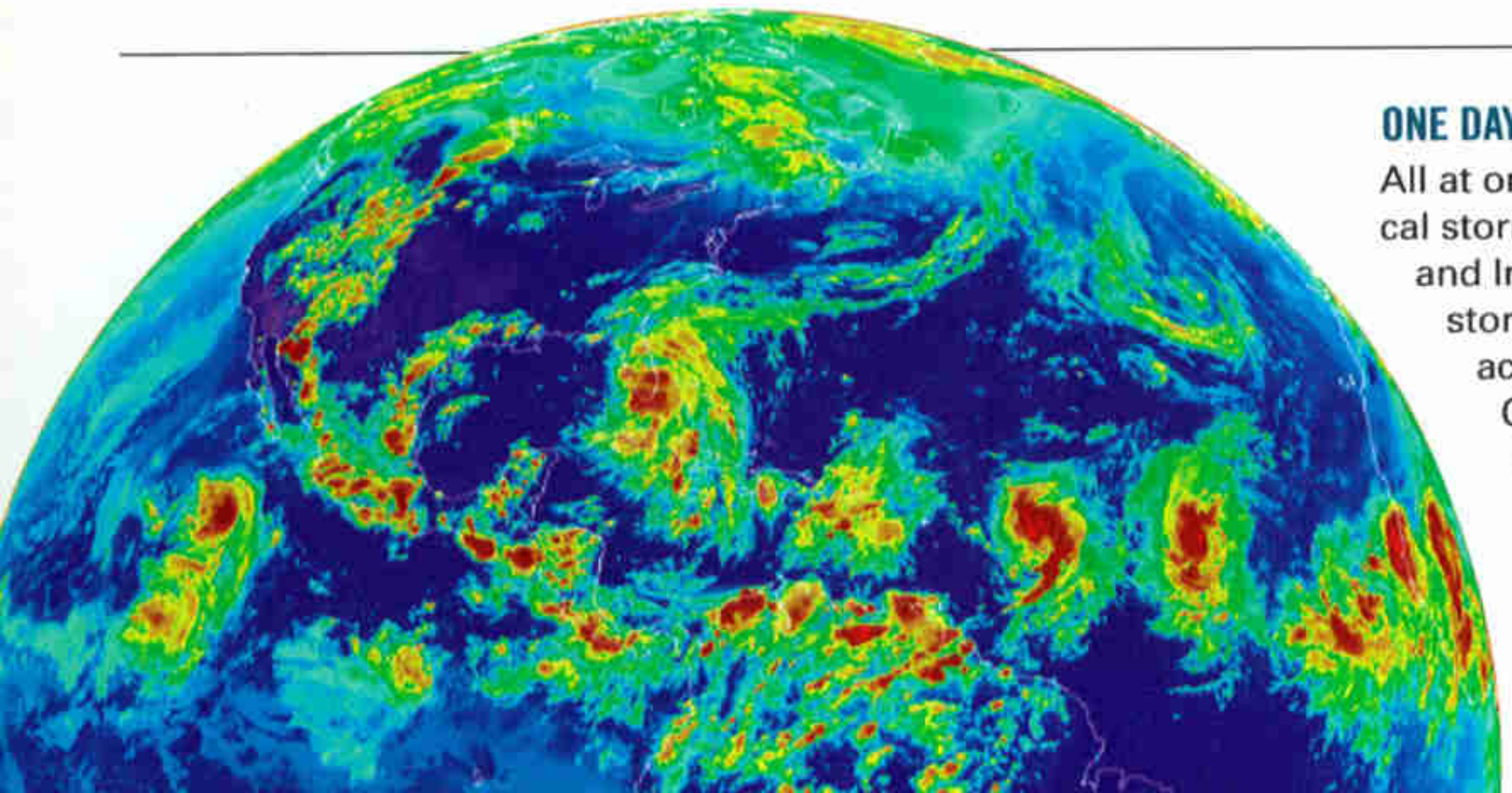
Sea-surface temperature (°F)

76	78	80	82	84



"A hurricane affects its own intensity by interacting with the ocean," says Isaac Ginis, an oceanographer at the University of Rhode Island. This is how it happens: Warm water at the top of the ocean fuels a hurricane. As it spins, the hurricane churns the water beneath it, bringing cooler water up from the depths (right). The cooler the water that it brings up, the less fuel the hurricane has. In the Caribbean, where even the deep water is warm (far right), hurricanes tend to be more powerful. In the Gulf of Mexico (above), where the warm layers of water are shallower, "hurricanes essentially kill themselves," explains Ginis. In September 1988 Hurricane Gilbert illustrated that difference, reaching wind speeds of more than 175 miles an hour early on but weakening once it moved across the Yucatán Peninsula into the Gulf.

Traditional predictions of hurricane intensity have been based primarily on changes in the atmosphere. Taking into account subsurface sea temperatures, Ginis created a model that improved intensity forecasts by 30 percent last year. "The U.S. spends $700,000 a mile to prepare a coastal area during a hurricane warning," he says. "A more skillful forecast will reduce the size of the area on alert, so we're talking about big potential savings."



ONE DAY, SIX TEMPESTS

All at once, on August 23, 1995, tropical storm Karen, Hurricanes Humberto and Iris, a tropical wave, and tropical storm Jerry (right to left) whirl across the Atlantic Ocean and the Caribbean Sea; tropical storm Gil spins in the Pacific. That year's Atlantic hurricane season, from June to November, and the four following ones were the busiest ever recorded.

Wake

Hurricane direction

Wake

Hurricane direction

Higher wind speed

Deep warm water

Cool water

Caribbean Sea

Both the warm surface waters and the tepid intermediate layers are deep. A hurricane's churning brings up only tepid water, leaving the deep, cool water unstirred. The wake is cooler than the adjacent sea surface but not as cool as it would be in the Gulf of Mexico.

NOT TO SCALE

HURRICANE ART BY DON FOLEY
MAPS BY SYZYGYMEDIA; CONSULTANT: ISAAC GINIS, UNIVERSITY OF RHODE ISLAND
STORM IMAGE (BOTTOM LEFT): NATIONAL CLIMATIC DATA CENTER, NOAA

Deep Warm Waters of a Hurricane-fueling Zone
August 1999



Depth of 80°F water in feet

0
50
100
150
200
250
300

DATA PROVIDED BY NAVAL OCEANOGRAPHIC OFFICE

Sea-Surface Temperatures, Atlantic Basin (1903-1995)

Warmer than average

Cooler than average

Number of Major Hurricanes (Category 3-5) to Hit the U.S. East Coast

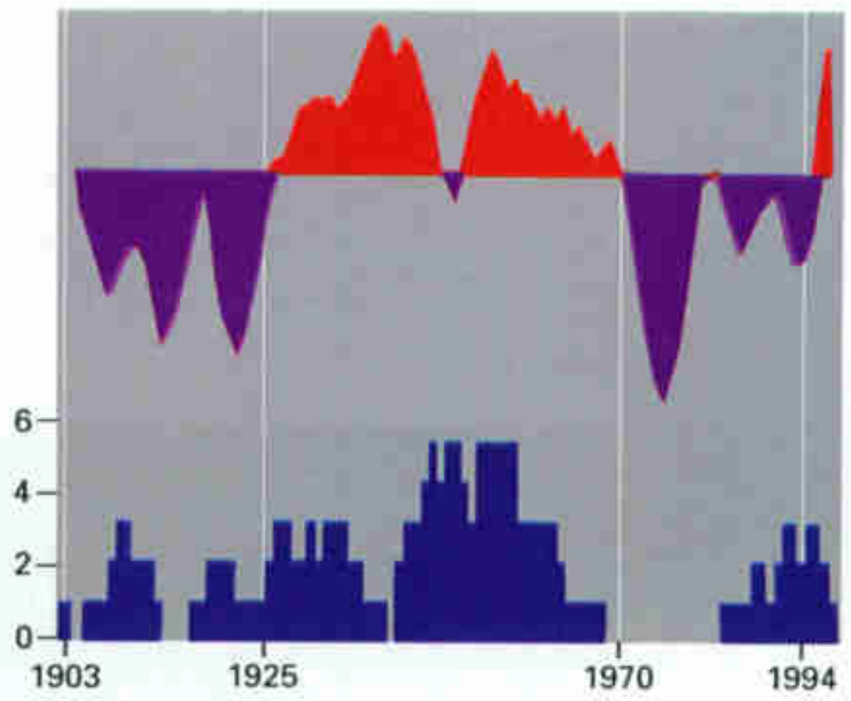


FIGURE PROVIDED BY C. W. LANDSEA, HURRICANE RESEARCH DIVISION, NOAA

ARE DECADES OF BIG STORMS ON THE WAY?

Over the past century average sea-surface temperatures in the Atlantic have run in cycles—one degree Fahrenheit cooler until 1925, one degree warmer from 1925 to 1970, then cooler again until 1995 (graph, left). The number of major hurricanes doubles when the ocean is warmer. In 1995 another warm phase seems to have begun. "It's a bit of a wake-up call," says Chris Landsea, a NOAA meteorologist.

only the surface of the ocean, its thinnest skin. How to see the vast part of the ocean that is hidden and track its motions?

In the 1950s the great physical oceanographer Henry Stommel, then a young scientist at Woods Hole, set out to investigate a deep current running counter to the Gulf Stream along the western boundary of the North Atlantic. His belief that the current flowed swift and vigorously flew in the face of the prevailing view that deep currents were sluggish rivers that barely crept along the bottom. Stommel imagined a way to measure a subsurface current: tracking a weighted float that would drift at a constant depth.

About the same time John Swallow, a British oceanographer, was crafting just such an instrument, a float that could drift for days at a set depth, emitting an acoustic signal that could be tracked miles away through hydrophones on a research ship. When Stommel heard of Swallow's float, he suggested that it might serve to verify his idea. In 1957 oceanographers released a set of floats in the deep waters off the coast of South Carolina and found that they did indeed move south at a good pace, confirming Stommel's notion of a deep, energetic countercurrent.

The invention of the Swallow float revolutionized oceanography. For the first time scientists could trace the pathway of a parcel of deep water and chart the ocean's movements in its invisible depths.

In the past half century such floats have grown considerably more sophisticated. On board the *Thompson* is a sleek, missile-like float with an unwieldy name: the Profiling Autonomous Lagrangian Circulation Explorer, or PALACE. A roving CTD, the PALACE does its work yo-yo style, descending to a selected depth as far as a mile down and drifting with currents at that depth for a week or so. At predetermined intervals it rises, measuring the temperature and salinity of the layers through which it ascends, pops up to the surface to transmit its data to satellites, and then descends and starts the cycle again.

PALACE floats can perform for several years, tracing the patterns of deep currents moving over the globe and giving scientists a virtual presence in places they can't—or don't want to—be, on the ocean in the eye of a hurricane, for instance, or in the surly Labrador Sea. Hundreds of PALACE floats are in place in the Atlantic. Maps plotting their spaghetti-like trajectories are revealing the ferocious complexity of the ocean's deep motions.

Forward of the *Thompson*'s galley is a spacious library and conference room where students meet daily to hear lectures by Tom Sanford and Susan Hautala, both professors of oceanography at the University of Washington. One balmy morning, ushered in by a brilliant



double rainbow, the students are grappling with the ocean's confounding variability, the mess of moving, mixing, and swirling occurring at all scales of time and space, from giant ocean gyres fomented by crosscurrents and undercurrents down to turbulence measured in millimeters.

There are internal waves that travel along the boundary between two layers of water with different densities. Among these are Rossby waves, giant, planetary-scale waves controlled by the Earth's rotation that carry indications from one side of an ocean basin to another of climatic warming and cooling and the associated changes in wind patterns. In the abyss is a complex kind of vertical mixing, the main way in which deep, cold water from the Poles warms enough so it can rise to the surface and complete its world journey. By releasing chemical tracers in the deep ocean and measuring their spread, scientists have lately found that this vertical mixing occurs around the rougher regions of the seafloor, where flow over jagged hills and valleys creates strong internal waves, cataracts, and eddies that force different layers of water to intermingle.

All this motion—the great, slow stirring of the ocean's large-scale circulation and its strange, chaotic internal "weather"—has tremendous effects on sea life, influencing the reproductive cycles of creatures from microbes to leviathans. The blue shark, *Prionace glauca,* migrates in a giant clockwise sweep around the Atlantic Basin from breeding grounds to feeding grounds, speeding its progress and minimizing its energy demands by riding the currents of the North Atlantic gyre. The larvae of those strange creatures populating deep-sea vents—giant tube worms, white crabs, flowerlike sea anemones—travel from one vent field to another by following the sweep of bottom currents. The fluctuating warmth and strength of currents can even foster the growth of bacteria and viruses of terrible virulence.

The great thermohaline swap of surface and deep water allows life to exist at all depths, from the sunlit surface to the dark, weighty gloom of miles-deep water. When young, cold water recently in contact with the atmosphere sinks, it carries dissolved oxygen to the deep sea. When chilled water masses from below rise, or upwell, they hoist nutrients from the deeps to the surface, where plankton grow fat and happy, making tasty food for larger organisms—copepods, fish, on up the scale to whales.

Even in the high seas of the mid-latitudes, where conditions can conspire to create great swaths of open water as smooth as a millpond, ocean currents foster life in surprising ways. Though long considered barren, stagnant pools deserted by upwelling and forgotten by winds, these ocean deserts periodically support little explosions of life. A good example is the Sargasso Sea, encircled by the North Atlantic gyre. "From month to month you see incredible fluctuations in the Sargasso," says Dennis McGillicuddy, an oceanographer at Woods Hole. "One day you go to a single spot and it's



DAVID DOUBILET (LEFT), KARL HELFRICH (RIGHT)

FLUID MECHANICS

Upwelling around a Pacific Ocean seamount (left) supplies nutrients to support a whole food chain. Such features likely contribute to the ocean's circulatory overturning. At Woods Hole Oceanographic Institution in Massachusetts, Karl Helfrich uses a sliced cylinder to study water movement. Seen from above, the experiment simulates how a submerged ridge affects a current.



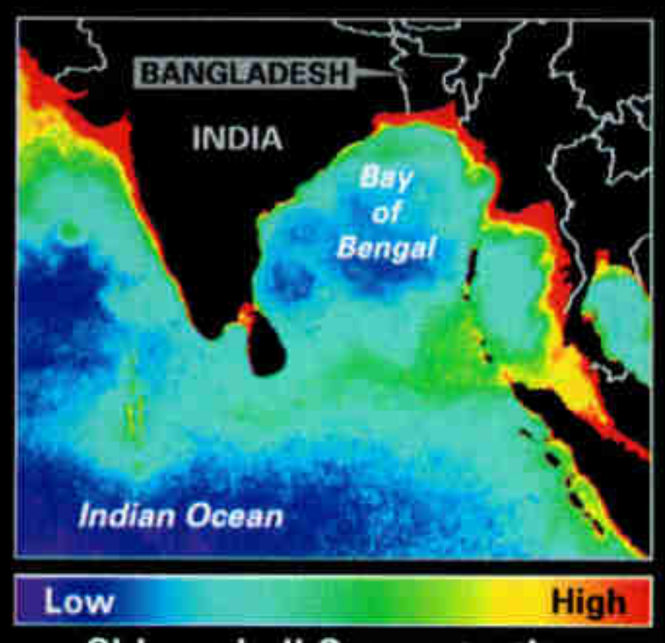
ASIA

FORECASTING EPIDEMICS

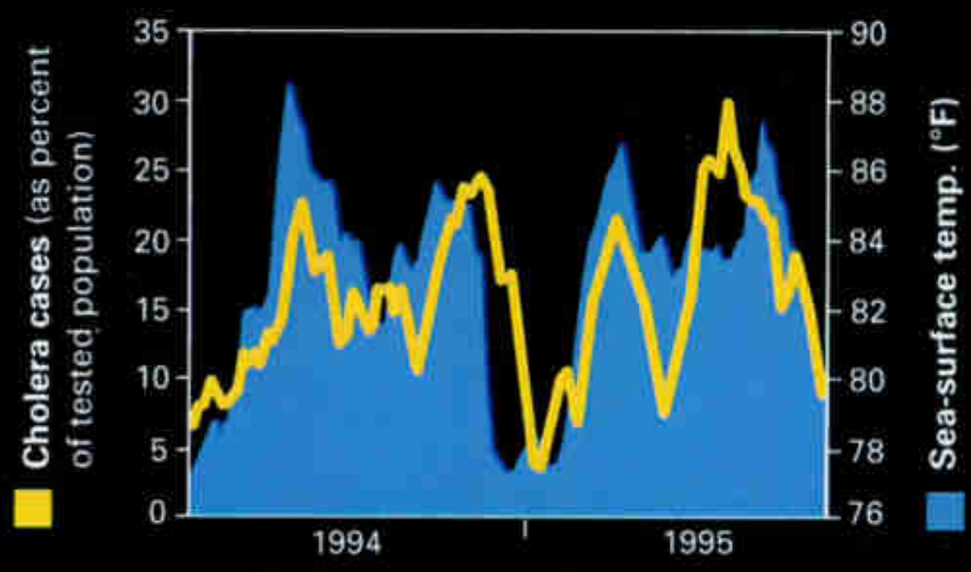
A mother soothes her sick child with a bath at the International Centre for Diarrhoeal Disease Research in Bangladesh. Twice a year, in late spring and summer, the number of cholera cases brought here for treatment soars. The increases follow the same pattern as spikes in sea-surface temperature in the Bay of Bengal (graph, right). They also occur around the time of phytoplankton blooms (top right), detectable by their chlorophyll.

Scientists have now figured out the connection. Warmer water encourages the growth of zooplankton, which carry the cholera bacteria, and the phytoplankton they feed on. Monsoons drive the plankton-laden water into estuaries, where the bacteria contaminate local supplies of drinking water. When the bacteria count reaches one million per milliliter, the water becomes infectious.

"Why not boil the water?" asks Rita Colwell, a microbiologist at the University of Maryland. "If you've never been to Bangladesh, that sounds logical. But there isn't sufficient fuelwood there." Her solution: Teach women to cover water-collection jugs with a filter of sari fabric folded at least four times (below).



Chlorophyll Concentration



Cholera Outbreaks Compared with Sea-surface Temperature, Bay of Bengal



SEAWIFS IMAGE BY BRADLEY M. LOBITZ, AMES RESEARCH CENTER, NASA (TOP); GRAPH: AMES RESEARCH CENTER

empty; the next day it's teeming with life. It has been a long-standing mystery: Where do the nutrients needed to fire such an explosion of planktonic growth come from?"

In 1997, with the help of satellite imagery, McGillicuddy and colleagues caught the Sargasso in the midst of just such a burst of productivity. In July of that year he was looking at satellite data that showed the telltale signatures of eddies swirling through the area ten times faster than the normal current. On short notice McGillicuddy joined a ship that was on its way out to the Sargasso. When the scientists got there, they were astonished. The ocean desert was blooming.

The eddies detected by satellite imagery, it turns out, are like little ocean storms stirring the waters of the Sargasso. Their turbulence lifts nutrients from the deep sea to the surface, creating hot spots of growth, oases in the blue desert.

EARLY THAT SAME YEAR the TOPEX/Poseidon satellite spotted another odd ocean phenomenon halfway around the world: an anomaly in sea-surface height in the western tropical Pacific. As the waters warmed, satellites and an array of buoys equipped with ocean and atmospheric sensors together monitored the growing strength of what would soon emerge as one of the strongest El Niños in decades.

Oceans were once thought to simply steady the climate, tempering its swings. Now we know that ocean currents are also intimately linked with intense climatic shifts. El Niño is the most famous of natural climatic oscillations in which ocean and atmosphere are partners, but other examples are turning up: the North Atlantic Oscillation and the Pacific Decadal Oscillation. These oscillations, which arise in part from shifts in the temperature and flow of water masses, profoundly affect climate in many parts of the world.

Even bigger climatic shifts may be in the offing. The past century has witnessed a startling alteration in climate, a general warming of the Earth's surface. We have been in a period of natural warming following the last Pleistocene glaciation, but evidence is mounting that human activity—the burning of fossil fuels, for instance, and slash-and-burn deforestation—is accelerating this trend. During the 20th century the average global temperature rose by about half a degree Celsius. The frigid top of the world is melting, and the sea level has risen four to ten inches.

"Global warming is real," says oceanographer Peter Rhines. "But it should also be called global storminess or global drought and deluge. A warmer world increases evaporation by boiling more moisture from the sea into the air. This may drive stronger winds, stronger storms. The moisture falls back to Earth as rain and snow."

A long-term fear is that this global warming and moistening might shut down the ocean's thermohaline circulation system, dislocating



SEA COCONUT
Manicaria saccifera
Origin: Orinoco and Amazon River Deltas
Size: 5 cm

the great system of currents and along with them the planet's climate patterns. The system depends on a delicate balance of heat and salt, explains Wallace Broecker; if one or the other changes, the system could collapse or change its course. A chemical oceanographer at the Lamont-Doherty Earth Observatory of Columbia University, Broecker has suggested that a rapidly melting ice sheet created a flood of buoyant fresh water in the North Atlantic at the end of the last glacial cycle, which reduced the sea's ability to roll over, slowing or stopping the descent of cold water, the engine of thermohaline circulation. This may have blocked the transfer of heat from the Equator to the Poles, bringing on a sudden episode of chilling for northern Europe about 12,000 years ago.

Some scientists think such abrupt changes in circulation could happen in the future, due

HITCHHIKING ON CURRENTS

THE SAGA OF SEA BEANS



SCREW PINE
Pandanus tectorius
Origin: Polynesia
Size: 6 cm

Seeds and fruits are among the world's most intriguing trans-oceanic voyagers. Their itineraries begin in the tropics, where plants drop them into rivers, estuaries, and coastal waters. Propelled by wind and currents and staying afloat for as long as 30 years, they can drift for thousands of miles. Beachcombers who collect them call them sea beans. They have always had an exotic allure. The sea hearts that Columbus collected on an Azores beach allegedly inspired him to sail west in search of their origin. The coco-de-mer was prized by peoples around the Indian Ocean for its reputed medicinal and aphrodisiac qualities.



ANCHOVY PEAR
Grias cauliflora
Origin: New World tropics
Size: 4-9 cm



TROPICAL ALMOND
Terminalia catappa
Origin: Asian tropics
Size: 8 cm



BOX FRUIT
Barringtonia asiatica
Origin: Polynesia
Size: 8-15 cm



PUZZLE FRUIT
Heritiera littoralis
Origin: Southeast Asia
Size: 6-9 cm



CRABWOOD
Carapa guianensis
Origin: New World tropics
Size: 1-6 cm



CORAL BEAN
Erythrina spp.
Origin: tropics
Size: 1-2 cm



SEA HEART
Entada gigas
Origin: New World tropics
Size: 6 cm



COCO-DE-MER
Lodoicea maldivica
Origin: Seychelles
Size: 46 cm

THE NEXT GENERATION OF SENSORS

With a window to the future, designer Doug Webb watches a test of his Slocum glider at Wakulla Springs, Florida. Still being developed, this remotely operated research robot will ultimately be able to undertake five-year missions. Webb sees a day when fleets of such gliders will make netting data from the ocean as routine as netting fish.



to the increased precipitation and ice melt brought on by global warming. During the past few decades oceanographers have discovered significant changes in some masses of ocean water, including a giant pool of surface water in the North Atlantic strangely less saline than the surrounding sea.

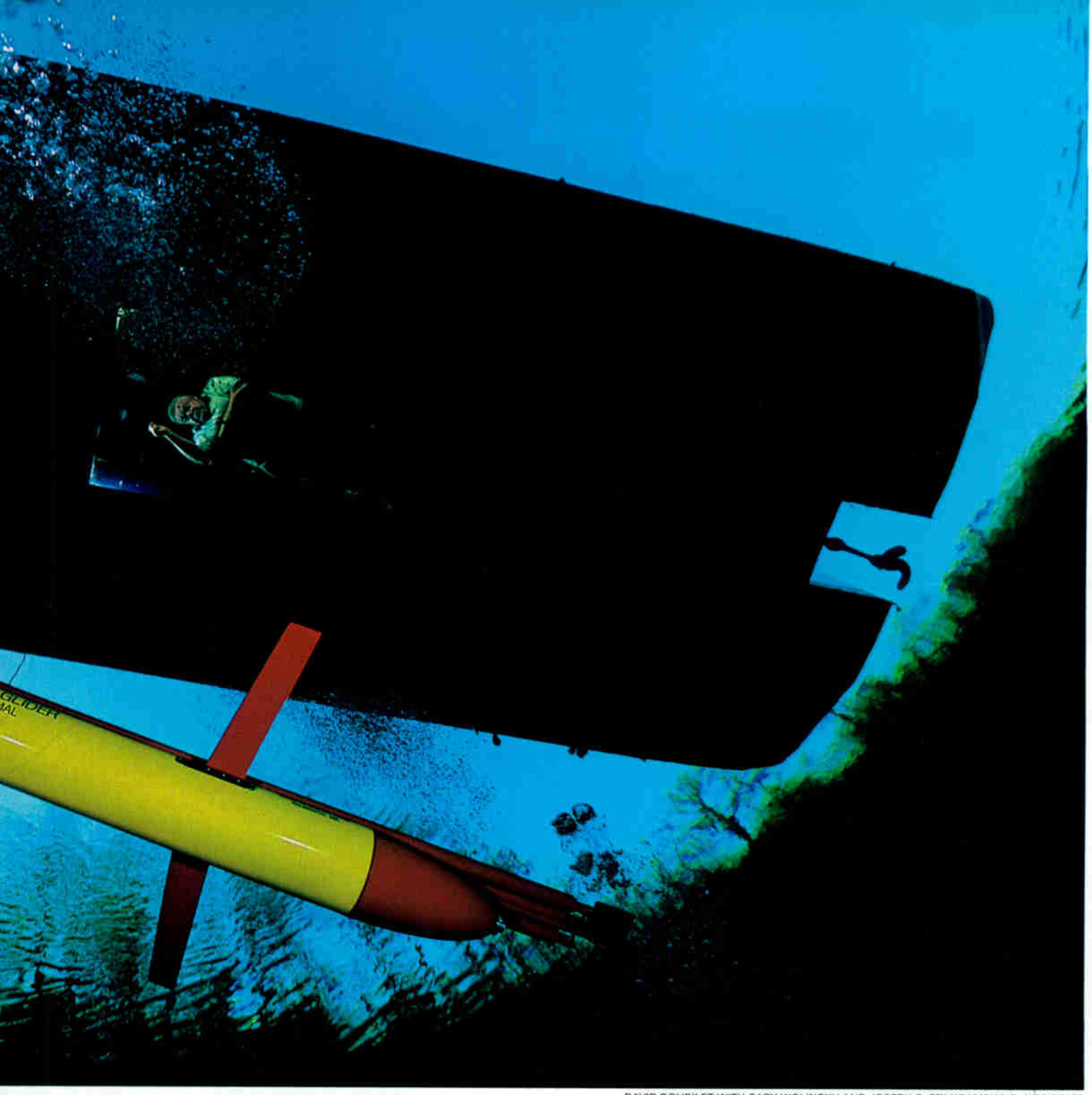
The data emerging from the CTD casts taken during the *Thompson*'s cruise point to slightly warmer water temperatures than those measured at this latitude 15 years ago. But it's far from clear whether the temperature change has anything to do with global warming. "The warming may be due to the fact that the data were collected in different months," explains Steve Riser, "or to a variability in air temperatures from winter to winter or to some other natural oscillation."

Still, says Riser, "everywhere we've looked, we've seen a warming and freshening of water and less deep convection. We don't know the reasons for these changes. Are they local? Global? We're not yet prepared to say."

The causes and effects of global warming are still under debate. But the possibility of long-term climate change has lent a new sense of urgency to oceanography and has spurred efforts to design systems for observing the ocean on a global scale. These include floats, moorings, and satellites that will monitor the ocean closely and measure changes in its surface height, its transport of heat and chemicals, the extent and thickness of sea ice. In 1999 the satellite QuikSCAT went into orbit to scan the ocean's surface daily, measuring the speed and direction of the winds that heat, cool, and stir the seas. And next year the satellite Jason-1 is scheduled to be launched to observe events such as El Niño and to monitor sea-level rise.

One group of scientists has used the probing "ear" of sound waves to determine whether the ocean might be warming. The speed of sound in seawater varies; with increased temperature sound travels faster. In a program known as Acoustic Thermometry of Ocean Climate, or ATOC, pioneered by Carl Wunsch and Walter Munk, underwater speakers send out bursts of sound, which are picked up by hydrophones moored to the seafloor thousands of miles away. "By taking repeated measurements of whole ocean basins over time," explains Munk, "ATOC can detect subtle warming in the deep ocean and spot long-term changes."

Last summer scientists launched Argo, an ambitious international program aimed at peppering the world's oceans with 3,000 PALACE floats to observe the seas in real time. "The Argo network of floats will complement Jason-1 and other satellites, giving us a view of the whole ocean from upper surface to



DAVID DOUBILET WITH CARY WOLINSKY AND JOSEPH S. STANCAMPIANO, NGS STAFF

deep currents," says Dean Roemmich, an oceanographer at the Scripps Institution. "They'll supply data that will keep climate models on track, helping to provide more reliable forecasts and to address some of the big questions of global climate change."

The hundreds of floats already in place in the Atlantic are generating a constant stream of data, revealing new patterns of ocean currents. To watch the trajectories emerge from these floats is to feel that this is the mapping of a new dimension of a new world—arriving just in time. With the specter of global warming a deep current of unease has come closer to the surface: the fear that we might be disrupting the giant pattern of ocean circulation, inviting climatic rigors and natural catastrophes of a magnitude we can only imagine.

As the *Thompson* nears Hawaii and the completion of its journey, squalls surround the ship, gray curtains that sweep rapidly across the water and deluge the decks. An albatross soars and tilts in our wake. The marvelous new mechanical eyes and ears of oceanography have taught us that the sea is unchanging only in its endless variety.

"There is still a huge amount of exploring to be done," says Steve Riser. "We need more data from every part of the world to try to understand the pieces of this immense puzzle and how they fit together."

If, as it seems, the motions of the ocean can so radically affect the life of the planet, the task is urgent. □

MORE ON OUR WEBSITE

Dive into a resource guide to oceans and more at **nationalgeographic.com/ngm/0010.**

NEW EYES ON THE OCEANS

DEEP SEA VENTS

SCIENCE AT THE EXTREME

With a mile and a half of Pacific Ocean sitting on their shoulders, ghost-pale crabs and fish forage among blood-red tube worms. Such communities flourish where super-heated water gushes from seafloor springs. Advances in the tools that scientists use to investigate deep-sea ecosystems are expanding knowledge of these creatures and their hostile environment.

BY RICHARD A. LUTZ
PHOTOGRAPHS BY EMORY KRISTOF

IN ASSOCIATION WITH WOODS HOLE OCEANOGRAPHIC INSTITUTION AND RUTGERS UNIVERSITY



STRANGE LIFE CLEARLY SEEN

WATER HEATED as high as 760°F by magma from Earth's interior billows from a sea-floor chimney (below). The surrounding ocean is just a few degrees above freezing. When the two fluids meet, iron sulfide precipitates, giving the "black smoker" its color. In these dark depths, chemosynthesis—based on thermal and chemical energy from the vents—is the primary mechanism sustaining life.

A living cloud flecks the water around a clump of limpet-encrusted tube worms and mustard-yellow mussels in the high-definition image at far right. With a magnifying lens on another camera the cloud resolves into a crowd of flea-like crustaceans called amphipods (right). Amphipod swarms like this one—observed at 9° N on the East Pacific Rise—may be the densest concentrations of invertebrate life on Earth.

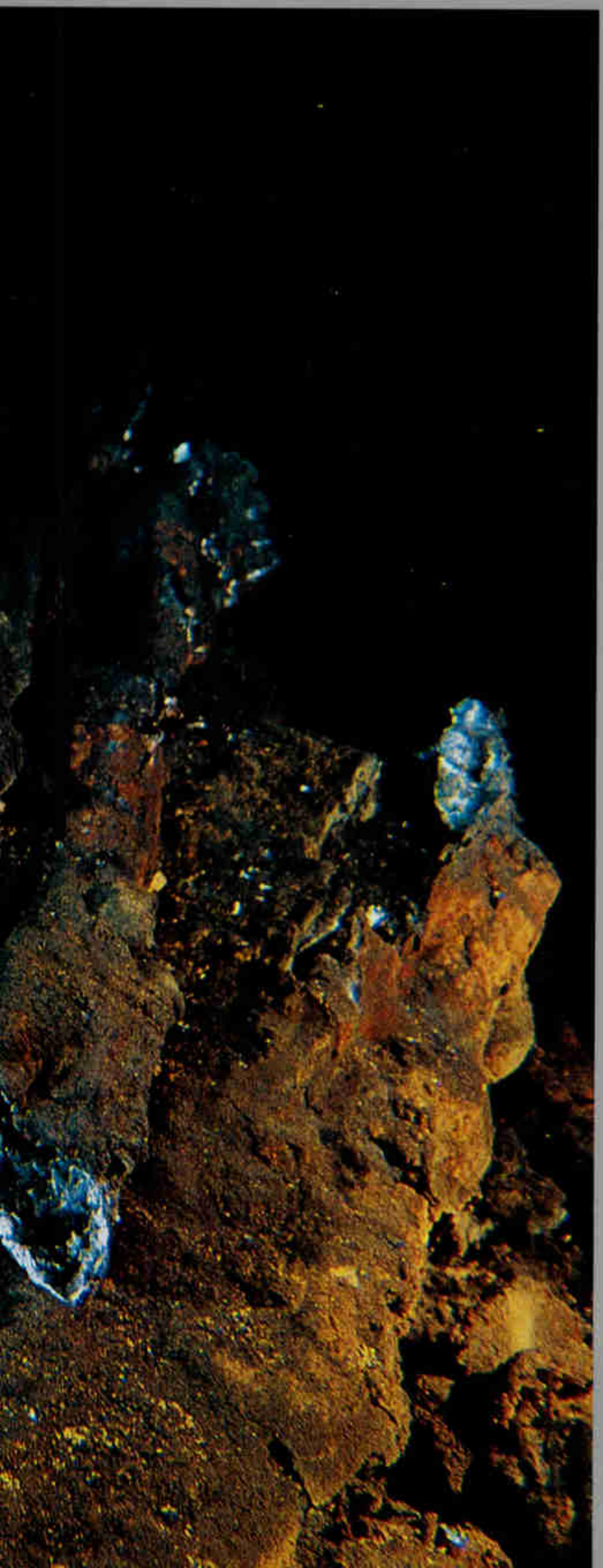
High-intensity lighting and





high-resolution imaging technologies provide researchers with the equivalent of a microscope to examine life in the deep sea. These tools can reveal organisms that have always been part of vent communities but have been hidden until now.

Timothy Shank, a marine

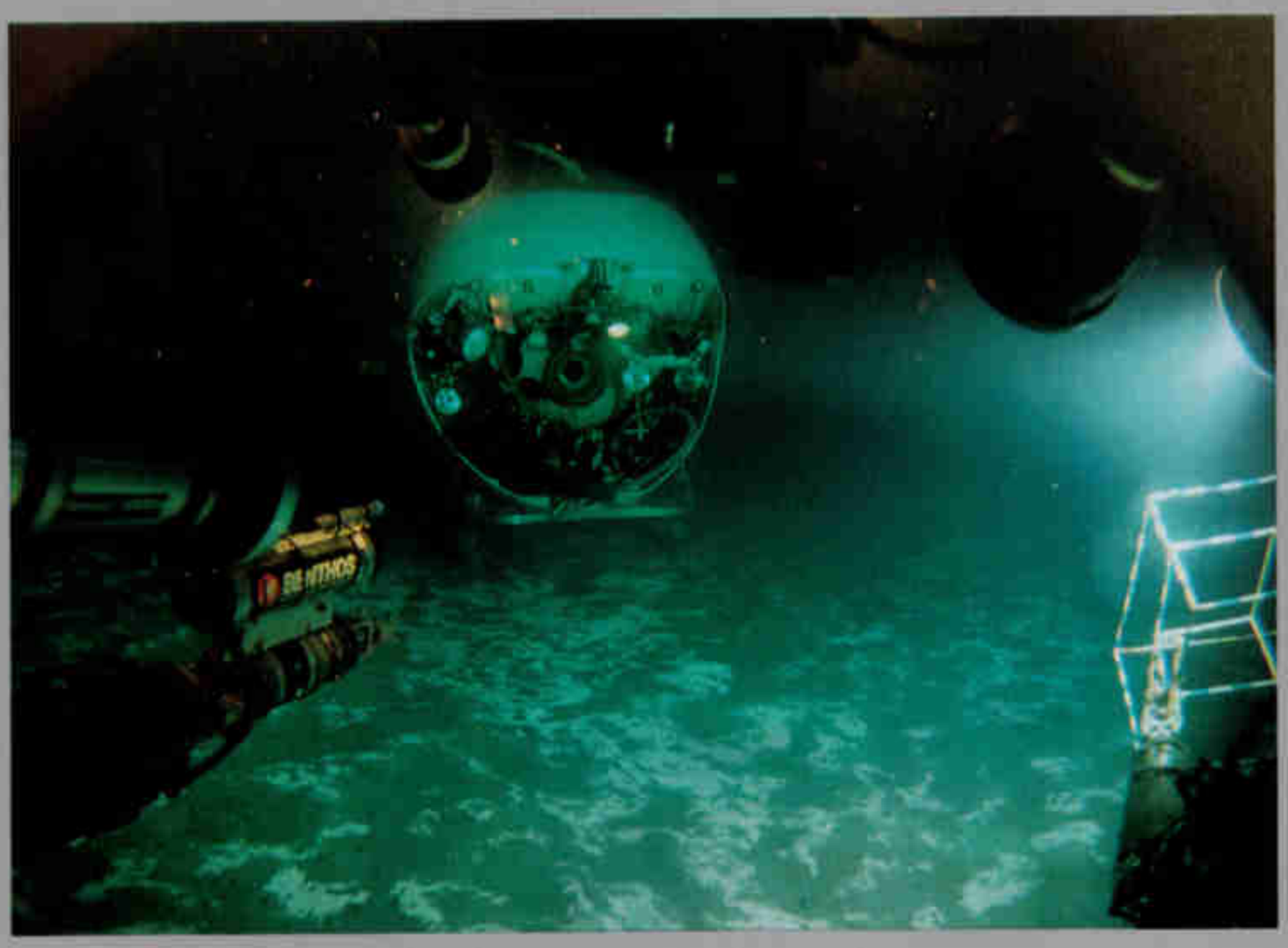




IMAX IMAGES FROM *VOLCANOES OF THE ABYSS*, STEPHEN LOW PRODUCTIONS (LEFT); MICHAEL V. DEGRUY (ABOVE)

ecologist at Woods Hole Oceanographic Institution, calls the array of previously unknown species found at vents "mind-boggling." He has calculated that, on average, a new species has been described every week and a half since biologists first visited the Galápagos Rift vents in 1979. "More than 20 years later," he says, "we're still on the tip of the iceberg. We're trying to understand relationships among vent animals—and we're still discovering new species!"

EVALUATING AN ARCTIC OASIS



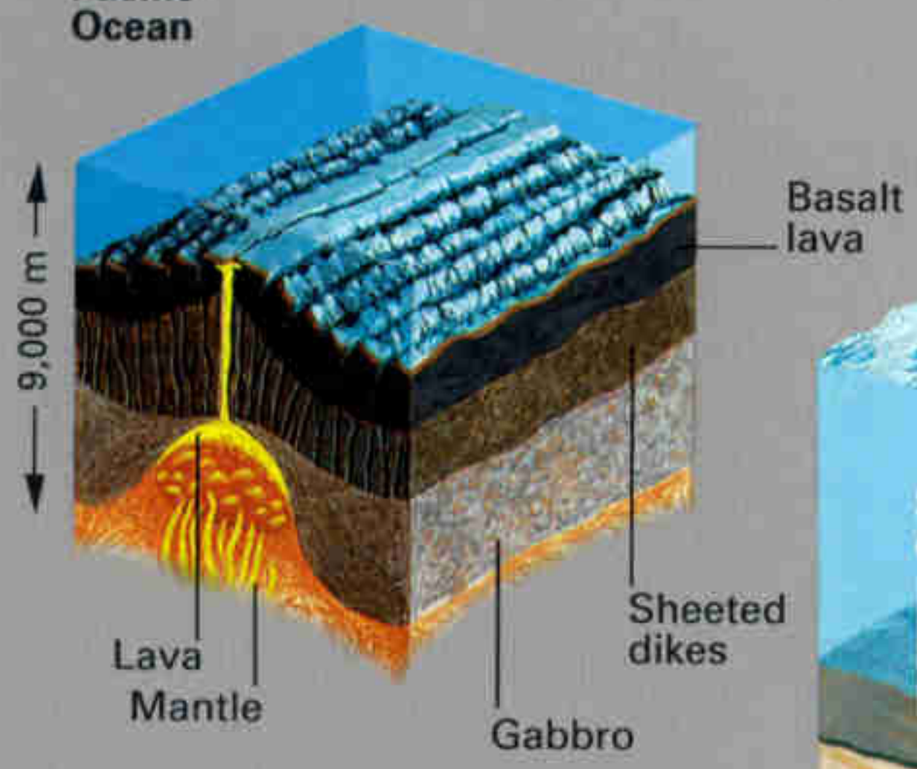
LAUNCH and recovery of submersibles (below) can become a daily drama in Arctic waters, where storms packing 45-mile-an-hour winds and 20-foot waves blow up rapidly. Undaunted by grueling conditions, scientists from Russia, Germany, Norway, and the U.S. Naval Research Lab (NRL) used Russia's twin *Mir* submersibles to investigate the Haakon-Mosby mud volcano 4,100 feet below the surface.

The team discovered "a chemosynthetic oasis," says NRL geophysicist Peter Vogt. It is populated by small worms, numerous eelpout fish, and nearly 20 previously unknown species of bottom-dwelling organisms. The team also found white bacterial mats growing on frozen methane hydrate that coated much of the seafloor around the volcano (left). If the Arctic Ocean warms by just a few degrees, as some climate-change models predict, massive amounts of methane could be released into the water column and then into the atmosphere, says City University of New York geologist Kathy Crane. "Methane is ten times more effective than carbon dioxide as a greenhouse gas," she notes. "The effect on climate could be powerful."

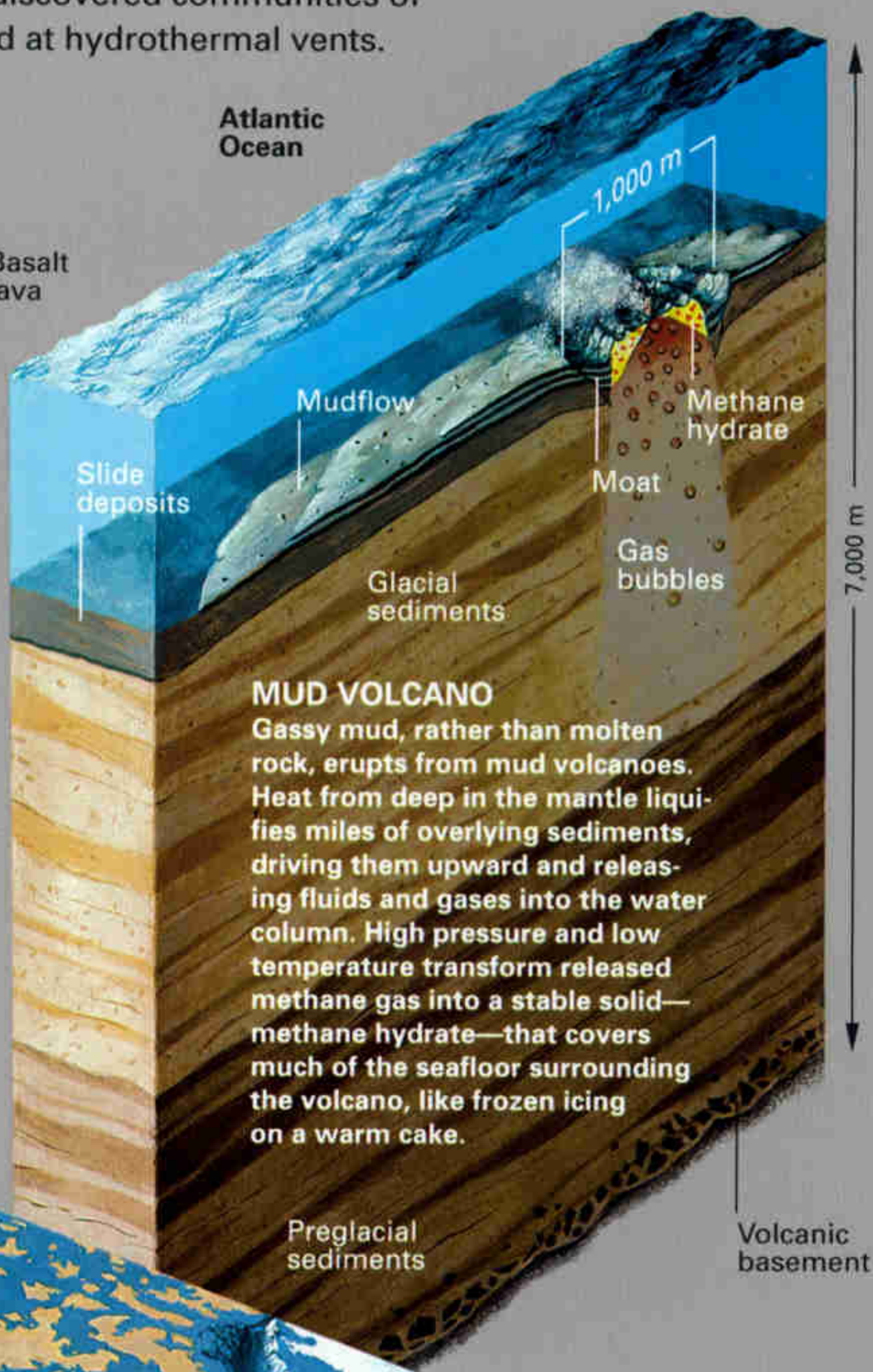


HOT SPOTS IN THE DEEP SEA

WE'VE STUDIED a handful of sites on the East Pacific Rise and Mid-Atlantic Ridge (map, bottom) in detail, but most of the 46,600-mile globe-circling mid-ocean ridge system still beckons—unexplored. Off the ridges, researchers examining deep-sea mud volcanoes have discovered communities of animals as exotic as those found at hydrothermal vents.

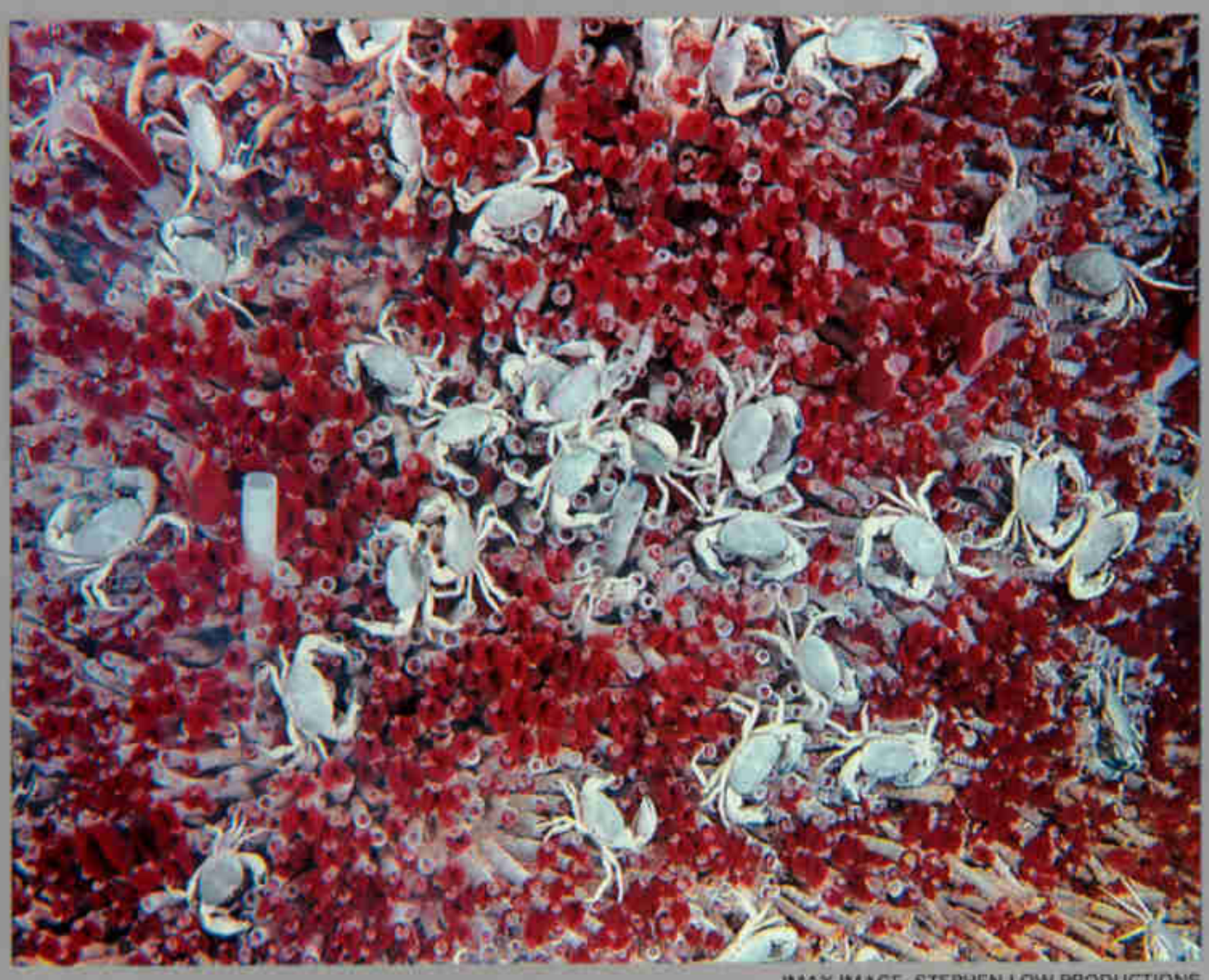


HYDROTHERMAL VENT
The Earth's crustal plates pull apart along the mid-ocean ridges, and lava surges up between them, cracking as it cools into new crust. Seawater penetrates fissures that can be miles deep; then, heated as it nears the magma layer, the water expands and rises rapidly. Heavy with minerals leached from surrounding rocks, it gushes from the bottom in fuming geysers or in lower temperature springs with a gentler flow.





ART BY NATIONAL GEOGRAPHIC ARTIST CHRISTOPHER A. KLEIN;
CONSULTANTS, ATLANTIC VENT: PETER VOGT, NAVAL RESEARCH LABORATORY;
KATHLEEN CRANE, HUNTER COLLEGE, CITY UNIVERSITY OF NEW YORK



IMAX IMAGE, STEPHEN LOW PRODUCTIONS

ARMORED BODIES and leathery tubes help shield some vent creatures, like the crabs and worms at left, from attack. Soft-bodied spaghetti worms (below) are defenseless—but prodigiously fertile. Each worm's body is lined with pill-shaped reproductive structures, primed to spawn a new generation.

The concentration of life at vents attracts deep-sea carnivores. A finned octopod (right) uses its powerful beak to devour prey, including bottom-dwelling crustaceans and worms.

MICHAEL V. DEGRUY



TEMPERATURES in a vent field can shift drastically and swiftly, especially near big smokers. Creatures that can't adapt equally quickly don't survive here.

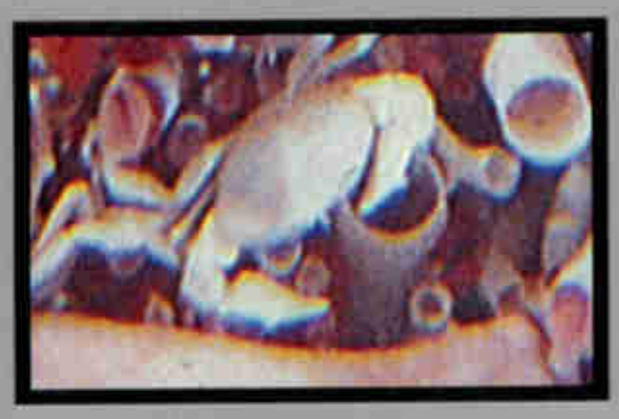
Some of my colleagues have nominated the worm *Alvinella pompejana* (right) as the most thermally tolerant animal on Earth. Whole galleries of alvinellids live in tubes on the sides of black smokers, at the very seething heart of the vent. University of Delaware marine biologist Craig Cary has gathered data that show alvinellids living in water that's 149°F and surviving frequent temperature spikes well above 175°F. The standard wisdom used to be that no multicellular organisms lived above about 130°F, but Cary thinks these worms do so routinely.

Alvinellids—on average a half inch in diameter and about three inches long—also tolerate the steepest temperature gradient on the planet. Specimens have been found in water 140°F hotter at one end of the animal than at the other. Superheated fluids from black smokers do not mix well with ambient cold seawater, so transitions between them are abrupt.

"Textbook biology tells us that animals can be psychrophilic [cold loving] or thermophilic [heat loving] but not both," says Cary. "I guess the alvinellids just didn't read the textbook."

We don't yet know how *Alvinella* worms survive these extremes. The answer may lie in their behavior or in some specialized cellular biochemistry, or both.

CAPTURING DEEP-SEA DETAIL



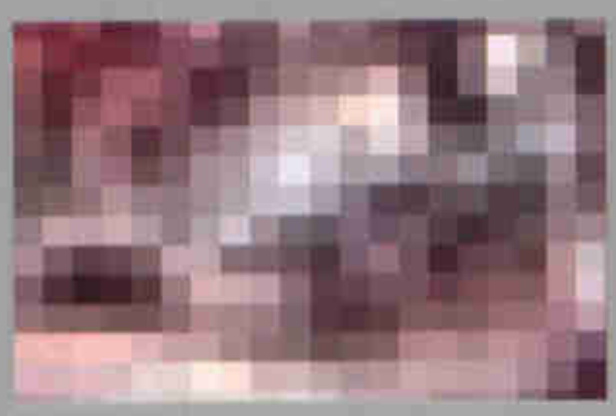
IMAX: With ten times the image area of 35-mm motion film, IMAX yields more detail than other media. All images have been adjusted to better illustrate the decrease in resolution.



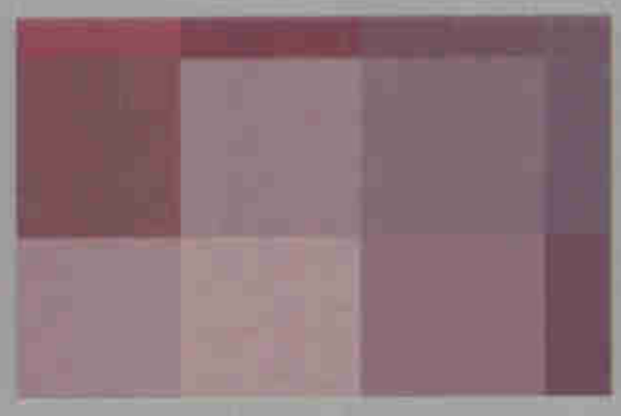
35-mm STILL FILM: Less flexible than motion-imaging tools, it offers relatively high resolution.



35-mm MOTION FILM: Despite limits, it's the familiar standard for evaluating image quality.



HDTV: Its resolution is equivalent to 35-mm motion film. Don't see it? Try squinting.



CONVENTIONAL VIDEO: Its resolution is one-sixth that of 35-mm motion film or HDTV.

VISITING A VENT is a dangerous and costly undertaking. Since the earliest dives scientists and image makers have worked with submersible pilots—who act as our eyes and hands on the seafloor—to create a photographic record of these rare experiences. The Woods Hole workhorse *Alvin* took us to 9° N in fall 1999. Woods Hole research specialist William Lange helped equip the submersible to allow photographer Emory Kristof, documentary filmmaker Mike DeGruy, and IMAX producer Stephen Low to shoot conventional video, high-definition video, and IMAX footage (right). Each tool has pluses and minuses; all produce pictures that look good on the printed page. But for scientists the critical characteristic is resolution. As the comparisons above illustrate, the technologies differ in how much detail can be recorded and in how far *into* an image we can look before clarity breaks down.

COMPARISON DATA BY CARLOS V. GIROD, JR., SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS



1979

AL GIDDINGS, SEA FILMS

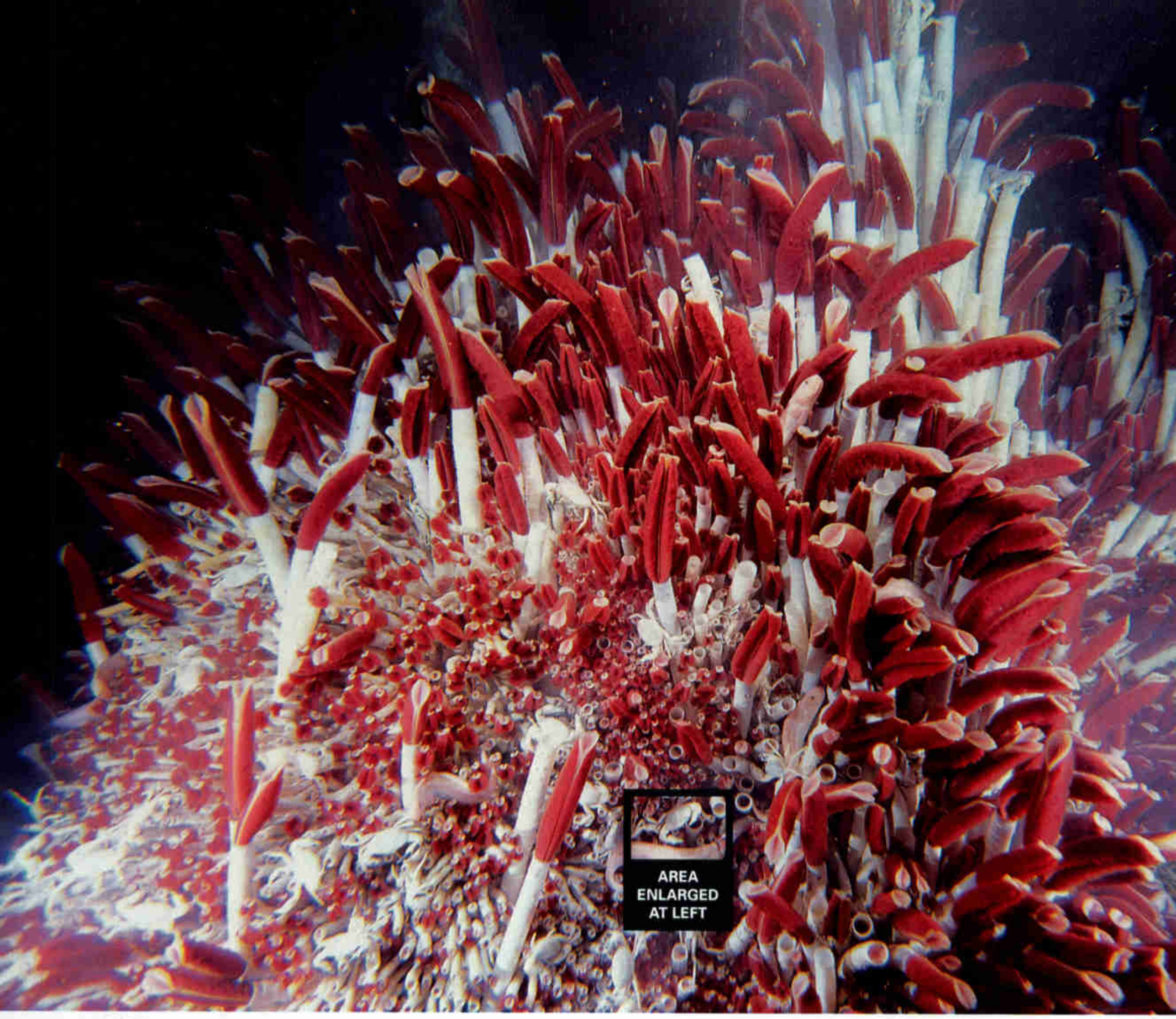
Vent creatures called dandelions typically disintegrate when they're brought to the surface. Early video images helped scientists identify the species as a colonial siphonophore—a tiny relative of the Portuguese man-of-war.



1993

AL GIDDINGS

Conventional video can't match the resolution of its digital descendants, but the technology—compact, relatively simple cameras using inexpensive, easily duplicated tapes—remains important for recording deep-sea observations.



1999

IMAX IMAGE, STEPHEN LOW PRODUCTIONS

A frame of IMAX film can fill a screen eight stories tall with astonishing detail. The unwieldy camera and thousand-dollar-a-minute film limit deep-ocean IMAX use, but images like this one come closer than anything seen before to capturing the experience of observing a thriving sea vent community firsthand.



1997

Shooting from about a foot away, a standard video camera with a macro lens fills its screen with a subject less than a half inch square. The bright orange spheres are tiny eyes on the head of a shrimp.

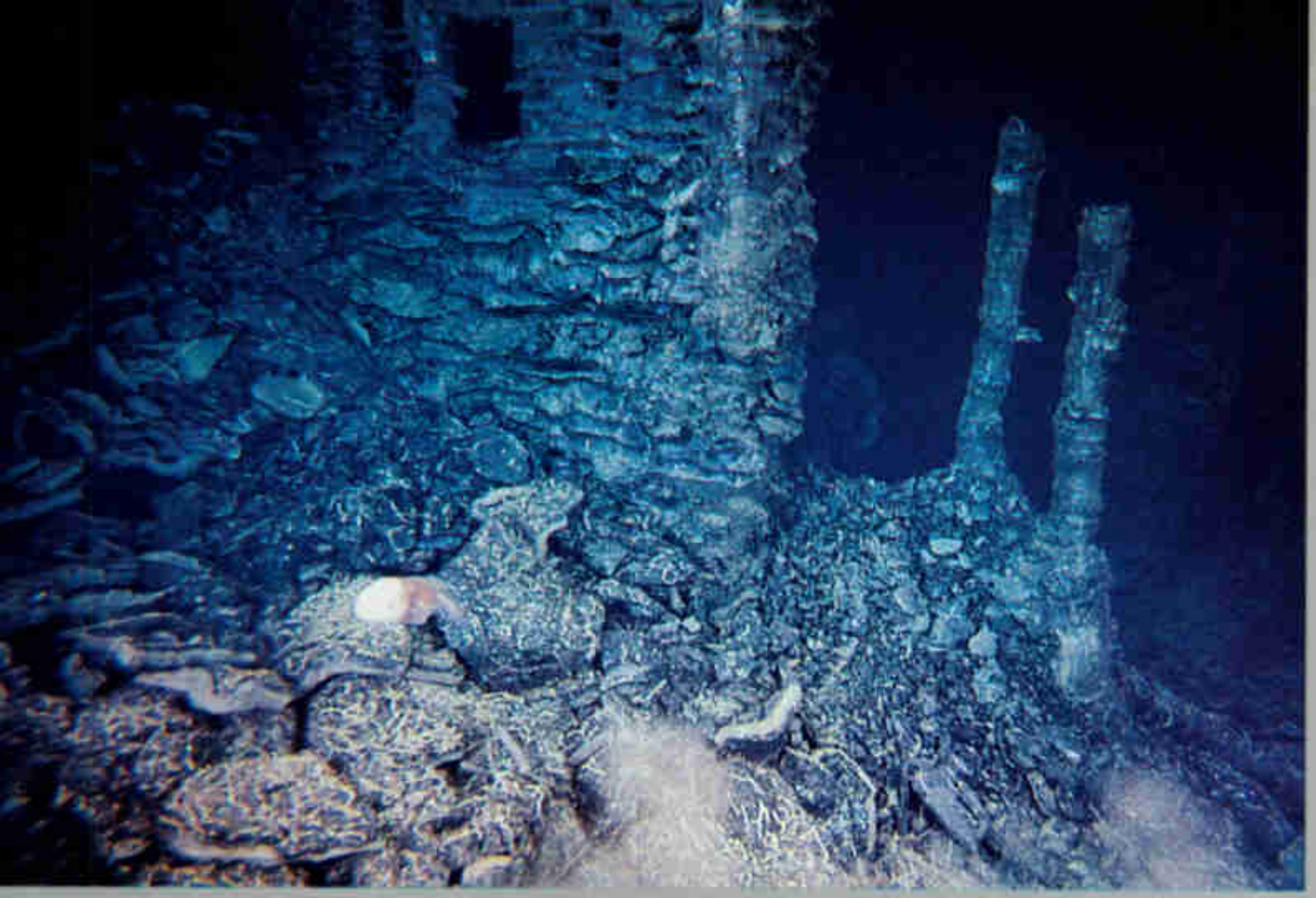


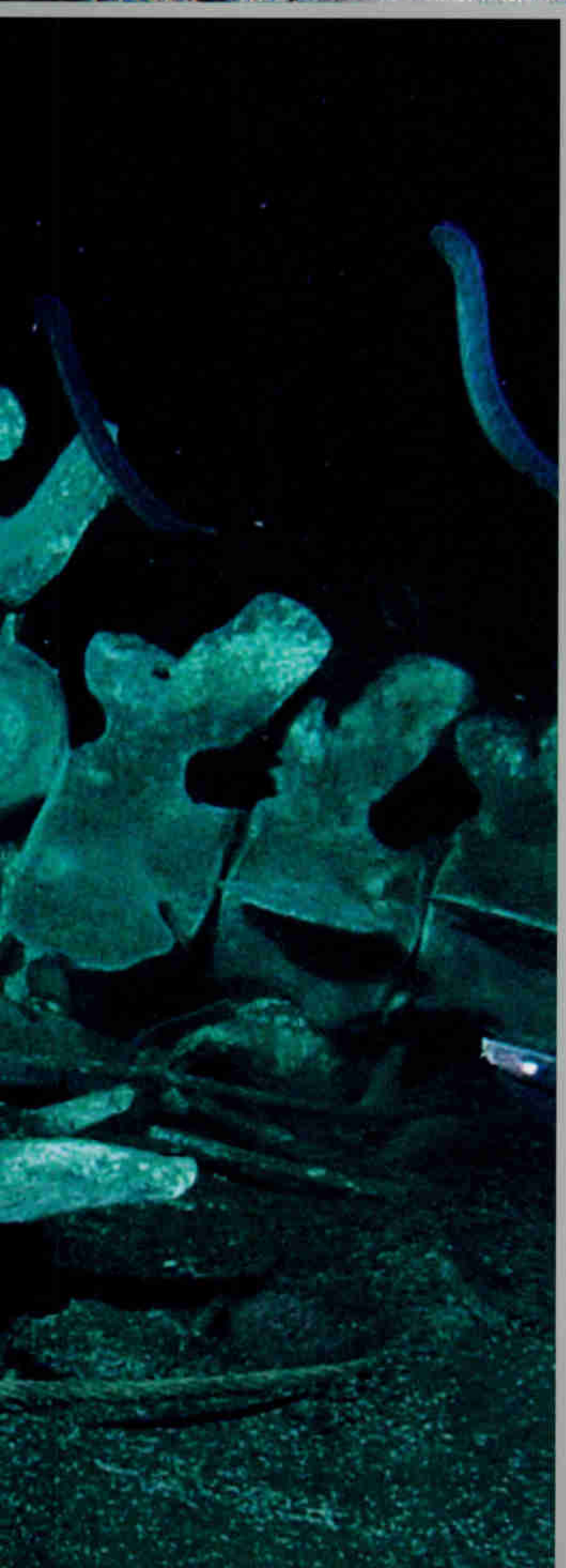
1999

MICHAEL V. DEGRUY

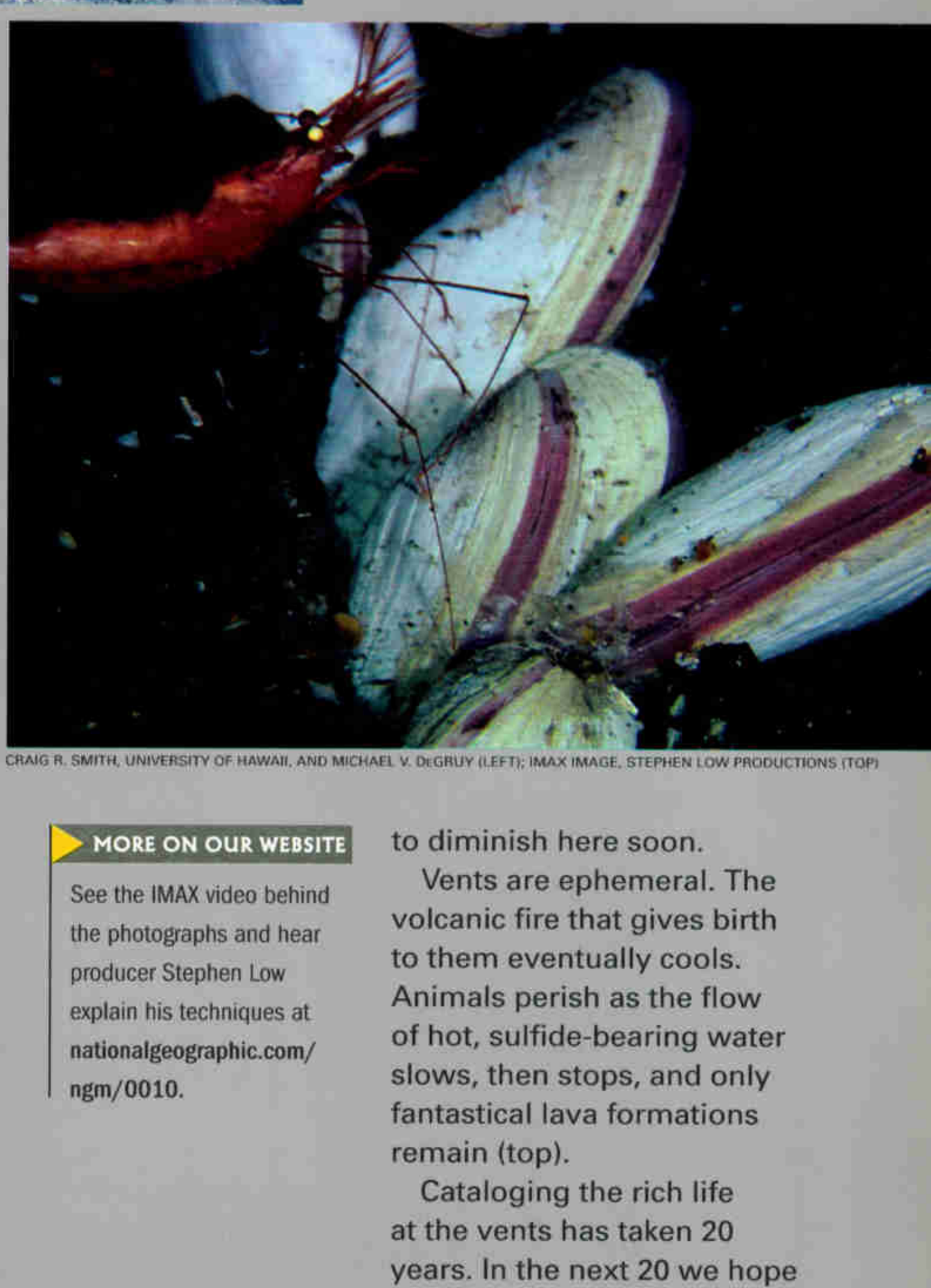
Fan worms use frilled limb-like structures to capture minute food particles suspended in the water. High-definition resolution and macro-lens magnification can now be combined to reveal each delicate anatomical detail.

STRIPPED TO BONE by scavengers off California, what was once a 35-ton gray whale still teems with life. "Whale falls" create microhabitats rich in the sulfide compounds vent organisms need to survive. University of Hawaii marine biologist Craig Smith has counted nearly 400 species colonizing such remains, including clams, limpets, and mussels also found at vents 1,000 miles away. He suggests that larvae drifting over ventless areas may settle on whale fall "stepping stones," mature, and release their own offspring, eventually dispersing populations among distant ridge systems.





GIANT CLAMS—typically among the last animals to colonize an active vent—have arrived in force at 9° N (below). Nearly a decade of observations suggests that hydrothermal activity is likely to diminish here soon.



CRAIG R. SMITH, UNIVERSITY OF HAWAII, AND MICHAEL V. DeGRUY (LEFT); IMAX IMAGE, STEPHEN LOW PRODUCTIONS (TOP)

MORE ON OUR WEBSITE

See the IMAX video behind the photographs and hear producer Stephen Low explain his techniques at **nationalgeographic.com/ngm/0010.**

Vents are ephemeral. The volcanic fire that gives birth to them eventually cools. Animals perish as the flow of hot, sulfide-bearing water slows, then stops, and only fantastical lava formations remain (top).

Cataloging the rich life at the vents has taken 20 years. In the next 20 we hope to understand the life histories of the creatures we've discovered. Exploring the origins of chemosynthetic organisms may also point us toward the source of the earliest life on Earth. □

Archaeoraptor Fossil Trail



O. LOUIS MAZZATENTA

When questions arose over the authenticity of Archaeoraptor, *one of the fossils featured in the November 1999 article "Feathers for T. Rex?," National Geographic asked Lewis M. Simons, a veteran investigative reporter, to look into what went wrong. Here is his unvarnished account.*

Its name—*Archaeoraptor liaoningensis* Sloan—is almost as long as its tail, but to my untutored eye the smattering of scrawny bones resembled nothing more than last Sunday's chicken dinner.

To some prominent paleontologists who saw it, though, the little skeleton was a long-sought key to a mystery of evolution. To others among this frequently hirsute and determinedly individualistic fraternity, it was a cheap hoax. And to Bill Allen, Editor of National Geographic, it was a giant headache.

Last November the magazine trumpeted the fossil's discovery in an impoverished region of northeastern China as providing "a true missing link in the complex chain that connects dinosaurs to birds" and patted itself on the back for helping fund the research. Two months later, when it turned out that the fossil had been artfully assembled from parts of unrelated creatures, that is, it was a fraud, Allen was in quick succession shocked, humiliated, and furious.

After cooling down, Allen asked me to try to find out what had happened. "Learn everything you can about it. How did we get into this mess? Who put this thing together? How did it make its way from a hole in the ground to our pages? Who's at fault? Let the chips fall where they may."

Assured of carte blanche, I traveled through parts of China and the United States, as well as up and down the halls of the Geographic in Washington; interviewed peasant farmers and Ph.D.'s, hucksters, journalists, zealots, and cranks; stared through microscopes, magnifying glasses, and into a room-size, lead-lined scanner; sent and received scores of documents, e-mails, faxes, and phone calls.

Using what I've seen, heard, and read, I've assembled a brief history of *Archaeoraptor.* It's a tale of misguided secrecy and misplaced confidence, of rampant egos clashing, self-aggrandizement, wishful thinking, naive assumptions, human error, stubbornness, manipulation, backbiting, lying, corruption, and, most of all, abysmal communication. It's a story in which none of the characters looks good. And, like the little rack of bones itself, this account inevitably is missing some bits and pieces.

The story began on an oven-hot day late in July 1997, when a farmer digging in a shale pit in Xiasanjiazi, in China's northeastern Liaoning Province, hacked out a thin, buff-colored slab measuring roughly a foot square. Like many of his neighbors, he regularly dug for fossils, which he sometimes sold to a collector or a dealer for a few dollars. But this piece was extraordinary: It contained the fossilized bones of what seemed to be a bird, including a faint aura of feathers and a beak lined with tiny teeth.

He'd been digging with a pick and shovel and had shattered the slab. Some breaks were edgewise splits through the plane of the fossil itself that resulted in what paleontologists term slab and counterslab, or part and counterpart. Something like an Oreo cookie pulled apart, they're essentially mirror images. Continuing to dig, he uncovered another, smaller slab a couple of yards away. This one contained a tail, rigid and about the size of a crocheting needle, a skull, a foot, and some other parts. It, too, was split into slab and counterslab. Pleased with the day's finds, the farmer scooped up the fragments, shouldered his tools, and walked the two miles or so back across the red dirt fields to his tiny brick house.

I do not know the name of this farmer, nor was I able to speak with him. When I visited Xiasanjiazi last March, no one I met acknowledged knowing such a person. I promised anonymity, but they had good reason to play dumb. A police official in the county seat, Beipiao, told me that only farmers authorized by the police may dig, and they must turn over their findings, in return for a small payment. Anyone keeping a fossil is subject to arrest. In the nearby city of Jinzhou a judge said that punishment could range from two or three years in jail to—in exceptional cases, such as when a fossil is smuggled out of China and sold abroad for tens of thousands of dollars—execution.

Archaeoraptor was taken to the U.S., where it sold for $80,000.

So, what I write of the farmer is based on what I saw in the village and in the pits and on relayed responses to questions that I left for him with

the dealer who bought the specimen from him.

In his one-room house, the farmer laid the counterslab of the tail aside. Using a homemade paste, he glued the slab of the tail to the lower portion of the birdlike body. With counterslab pieces from the body itself—and possibly other scraps he'd kept over time—he glued in missing legs and feet. Aware that fossil fanciers, unlike paleontologists, prefer specimens assembled and suitable for display, the farmer was following basic market economics.

The result was the "missing link"—the body of a primitive bird with teeth and the tail of a landbound little dinosaur, or dromaeosaur. In time the tail, and the question of whether or not it belonged where it was stuck, would wag the dinosaur.

Whether the farmer was deliberately creating a fraud to earn extra money or earnestly connecting fragments he thought belonged together, I can't say positively. According to his response to my queries by way of the dealer, he believed then and still believes that "the tail belongs to the body [and] was pushed away from the body when it was buried" more than 120 million years ago. But, when he found it, he had to have seen that the tail was connected to another body.

The dealer, with whom I spoke at length and whose name I will not disclose, for his safety, was the only character in the story who did not admit some culpability. He said he bought the fossil from the farmer in June 1998 and insisted that he had no knowledge then or now of it being a fake. "Fossils are my sole source of income, and I sell to the same people regularly," he told me. "I would be finished if I sold fakes." But he acknowledged that he often sold "composites." The difference, in his mind, is that a fake is created to fool the purchaser, while a composite is intended "to make the specimen look complete." I found this point too fine to grasp.

I have no doubt that the dealer knew he was smuggling, though he went to great pains to explain his way around Chinese law. Through a "partner" at a scientific institute in the city of Guilin, he obtained a paper titled "certificate," which states that the fossil was "legally acquired" and "is legal to be exported from China" as part of a "specimens exchange program."

A 1982 Chinese law prohibiting export of vertebrate fossils is now undergoing its sixth revision, and the dealer argued that "at the moment there's no law." While authorities in Beijing insist that no fossils may leave the country legally, the reality is that huge quantities are taken out, most through the expediency of bribing local officials.

The dealer sold *Archaeoraptor* in early February 1999 at a bazaar-style gem and mineral show in Tucson. The buyer, Stephen A. Czerkas, director of a nonprofit dinosaur museum in the small town of Blanding, Utah, told me he was "stunned" when he was shown the fossil in the dealer's motel room. Never doubting its authenticity, he raised the $80,000 asking price with a phone call to M. Dale Slade, a Blanding businessman and an active backer of the museum.

Czerkas and his wife, Sylvia, are artists who create life-size dinosaur figures, some of which are displayed in major museums around the world. They're utterly consumed by their work, and their home in the fields outside Blanding is filled indiscriminately with dinosaur kitsch and art, from plastic knickknacks and movie posters to paintings, bronzes, and textbooks. Although they've written books and papers, neither holds a doctorate. This is a sensitive nerve with them and an irritant to some Ph.D.-equipped paleontologists, who dismiss them as hobbyists.

The Czerkases and Slade anticipated the new specimen would become the crown jewel of the Blanding Dinosaur Museum. While intelligently conceived and attractively laid out, the museum is off the beaten track and draws about 9,000 visitors during the six months a year it's open, just covering expenses. They could see the fossil becoming a magnet for huge crowds of tourists as well as serious researchers. Despite their dream being shattered, neither Slade nor the Czerkases has attempted to get the $80,000 back. The dealer told me he has made refunds and exchanges in the past. "Why should we want our money back?" Slade asked me incredulously. "We got better than our money." According to him, the fossil has been appraised at "between $1 million and $1.5 million," and his company plans to write that off as a contribution to the Blanding museum.

In time the tail, and the question of whether or not it belonged where it was stuck, would wag the dinosaur.

A week or so after taking the fossil home, the Czerkases discussed it with an old friend, Philip J. Currie, a renowned Canadian scientist based at the Royal Tyrrell Museum of Palaeontology in Alberta. The couple wanted Currie to join them as co-author of a paper they would write. Currie was interested. Since he often consulted for NATIONAL GEOGRAPHIC, he mentioned it to Christopher P. Sloan, the magazine's art editor. Sloan thought there could be a story in the little fossil.

But Currie and Sloan didn't want to jeopardize their organizations' access to China by becoming associated with a specimen the authorities would doubtless consider smuggled. With difficulty, they convinced the Czerkases to return *Archaeoraptor* to China after completing the study. (The fossil was eventually handed over last May 25.)

At Currie's suggestion the director of Beijing's Institute of Vertebrate Paleontology and Paleoanthropology, which would receive the repatriated fossil, proposed that Xu Xing, a boyish-looking scientist at the institute, spend "three to five months" in the U.S. helping study *Archaeoraptor* and contributing to the scientific paper. As it happened, a jet-lagged Xu,

flown to the U.S. by NATIONAL GEOGRAPHIC, would spend just two days gazing at the fossil in Blanding before being pushed to the fore at a meeting with news media in Washington, where he had little to offer. His name on the paper would add no more than an exotic touch to the all-American cast. Ironically, it would be Xu who, two months later, dumped the whole story on its head.

Knowing that the fossil would be returned to China, Currie now felt free to become directly involved, and Sloan obtained Bill Allen's commitment to cover the story. A plan was cobbled together for the Czerkases and Currie, along with Xu, to first write a paper and have it published in the prestigious scientific journal *Nature*. NATIONAL GEOGRAPHIC—which attempts to bridge the gap between hard-core science and popular interpretation—prefers not to break scientific discoveries without having them peer reviewed in advance by scientists. The effort to coordinate publication between *Nature* and NATIONAL GEOGRAPHIC would eventually break down, contributing in large measure to the GEOGRAPHIC publishing a false article.

The *Archaeoraptor* story was originally to appear in the magazine as a small, subsidiary part of a broader piece on feathered dinosaurs. Sloan, who'd handled the artwork for numerous articles but never written a story, had convinced Allen to let him write this one. Publication was set for November, six months ahead.

The association of Sloan and Currie would prove to be star-crossed. As a first-time writer, Sloan committed the journalist's cardinal sin—he assumed that since Currie's reputation was so outstanding, there was no need to stay on top of him or question him. Currie became a collaborator rather than a source. Worse, Currie was so distracted by other commitments around the world that he gave the *Archaeoraptor* project short shrift.

Earlier, on March 6, Currie had flown to Blanding at NATIONAL GEOGRAPHIC's expense and examined the fossil for the first time. He raised the first red flag. "I realized that all was not right because you couldn't see a connection between the tail and body," he told me, "and clearly the legs were part and counterpart. I told Stephen. He agreed. It was obvious—you could measure the bones and see how they lined up." The Czerkases' recollection, however, is that Currie had mentioned only one of the feet—not a grave concern—and nothing about the tail.

Discrepancies like this kept cropping up as I interviewed those involved. With the negative publicity still hanging over them, people now recall widely differing versions of what took place. In the brilliance of hindsight, what may have been foggy at best then is perceived as razor-sharp now. Few accept blame; everyone accuses someone else.

There would be more red flags. But because Allen had ordered a thick blanket of secrecy over the project, they went unseen or unreported. Had any of these warnings filtered through to him, Allen now says, he would have pulled the plug.

In a most damaging lapse of responsibility, Currie did not tell Sloan about his concern. He said he assumed the Czerkases would. They say there was no reason to. In May, Sloan visited the Czerkases himself and had his own look at the fossil. An avid dinosaur enthusiast but no scientist, Sloan was very excited. "I had no doubt that it was a weird animal," he said, "but I had no reason to suspect that it wasn't legitimate. I'd worked with Phil for years, and he'd seen it." Blindsided by his esteem for the scientist, Sloan neglected to question Currie thoroughly.

Currie's involvement was key to NATIONAL GEOGRAPHIC's own. Later in the preparation of the article, when Bill Allen told his editors to keep strict confidentiality, Kathy B. Maher, the senior editorial researcher assigned to check it for accuracy, recalls she wasn't troubled, "because Phil was on the job, and I trusted him implicitly." Currie now acknowledges that he dropped the ball. "Definitely, I should have flagged the GEOGRAPHIC directly and not relied on others to do it." As the project moved inexorably toward publication, he was in the field, darting from Canada to Mongolia to Europe to Argentina, largely ignoring what was happening in Utah.

On August 2, Currie joined the Czerkases briefly in Austin, at the University of Texas High-Resolution X-ray CT Facility founded by professor Timothy Rowe. Using a device the size of a kitchen dining nook, Rowe and his aides had scanned the fossil for more than a hundred hours and generated a series of pictures that appeared to show numerous breaks, 88 pieces in all. Some of the fractures seemed to be between unmatched pieces, skillfully pasted over. Rowe, ruggedly handsome and casually profane, agreed to charge a discounted rate of $10,000 for the scans—paid for by a National Geographic Society grant to Currie—in return for being included as another co-author of the paper.

By the time Currie walked into the basement-level lab, Rowe and the Czerkases had gone over the pictures. According to what Rowe told me, the scans revealed that "the tail had no natural connection to the body," and he explained this to Stephen and Sylvia. "It was hard to do, but I told them the fossil had been badly shattered and put together badly—deceptively—and there was a chance that it was a fraud. They were badly affected. I didn't know at the time that they'd invested $80,000 in it."

Currie remembered, though, that by the time he'd entered the room, "Stephen and Sylvia and Tim had come to agreement that [the body and tail] did belong together." Over the next several hours, however, it became apparent that Rowe, as well as Currie,

was uncomfortable with this. But they succumbed to the Czerkases' pressure. (Had Xu Xing never lucked into the farmer's second fossil, Currie and Rowe could be basking in *Archaeoraptor*'s and the Czerkases' shared glory today.) So, they contented themselves at the time with voicing reservation in private and never demanded that their doubts be strengthened in print. Stephen had insisted that they move ahead quickly and play down their differences because NATIONAL GEOGRAPHIC was on deadline, said Rowe. This was true, but according to Bill Allen, "if anyone here had any inkling that something of this magnitude was wrong, I'd have stopped it, even on the day the magazine went to press [September 19], even though it would have cost us as much as $200,000."

The Czerkases' own take on what happened was that Rowe's CT scans were "inadequate," that they showed "less than what was visible to the naked eye," and that Rowe was "jumping on" the break between the tail and the body "in order to justify the importance of his lab." A key element of the disagreement between Rowe and the Czerkases turned on ego and personality: Rowe disdaining the couple for their "controlling ways" and lack of formal education, and they biting back at him as "an ivory tower elitist, ambitious to the point of being willing to sacrifice anyone."

As Currie left, a National Geographic Television team arrived at Rowe's lab to film *Archaeoraptor* for a program on feathered dinosaurs. No one informed the TV crew or Sloan back in Washington of the discrepancies they'd just discussed. Rowe told me that since he was "just a hired hand" and that the Geographic's funding had gone to Currie, he owed Currie confidentiality. Besides, he added, "you know what happens to the messenger bearing bad news. Little did I know that Stephen and Sylvia would suppress it." Red flag number two.

Currie dispatched Kevin Aulenback, a fossil technician at the Tyrrell Museum, to Blanding the first week in September to "prep" the specimen—a painstaking process of microscopically cleaning the bones and removing the surrounding dirt of millennia so that scientists may better examine the fossil. Things got off to a bad start. Aulenback said he was certain that pieces had been amalgamated, though he couldn't say if the pieces came from one animal or more. The Czerkases angrily replied that his evidence was insufficient. On the plane back to Alberta, Aulenback wrote a detailed and acerbic memo of his findings and e-mailed it to Currie, then in the Gobi desert, concluding that *Archaeoraptor* "is a composite specimen of at least 3 specimens . . . with a maximum . . . of five . . . separate specimens." He did not send it to the Czerkases. This third red flag was not relayed to Sloan either. When Sloan asked, "How did the preparation of *Archaeoraptor* go?" Aulenback replied with excruciating specificity, "Preparation of *Archaeoraptor* is quite good."

"Why not tell him about your findings?" I asked. He replied: "If he'd asked me what I *thought* about the fossil, I would have told him. But that's not what he asked."

In Washington, Sloan recalled, "we were only waiting for Stephen and Phil to agree on whether *Archaeoraptor* was capable of flight. Once they decided that it was, I went to Bill and told him, 'This is hot.'" Allen agreed to move the *Archaeoraptor* segment up and make it the dramatic lead of the story.

Allen agreed to move the *Archaeoraptor* segment up and make it the dramatic lead of the story.

At about the same time, on August 13, after rewriting and revising their paper perhaps 20 times, the scientists submitted it to *Nature*, sending it by express mail from Blanding to London, with a copy to Sloan in Washington. Titled "A New Toothed Bird With a Dromaeosaur-like Tail" and under the names of Stephen Czerkas, Currie, Rowe, and Xu, it stated in the lead paragraph that "the primitive bird from China . . . is more derived . . . than *Archaeopteryx*, the oldest known fossil bird . . . [and] has elongate rod-like extensions . . . remarkably like those in dromaeosaur dinosaurs."

On its second page the paper pointed out, though with no alarm, that "counterslab pieces of the right leg had been incorporated into the main slab in the position of the left leg [and] the tail is probably from the counterslab." These problems were repeated on a later page.

Sloan acknowledges that "in 20/20 hindsight, alarm bells should have gone off" when he read this. "But all those months ago, I probably read right over it and thought, Well, all those scientists don't seem to think anything is strange. I certainly didn't see any hint that the tail or anything else came from another critter."

On its fifth page the paper stated that the dromaeosaur-like tail on a birdlike creature suggested a previously unknown element in the evolution of birds from landbound dinosaurs. In short, this was what Czerkas would tell NATIONAL GEOGRAPHIC was "a missing link."

Finally, the paper contained a hand-drawn figure of the skeleton, with the right leg and foot and tail shaded. The leg and foot, the caption stated, "are counterslab elements that were cemented to the main slab. We believe the tail to have been cemented from the counterslab as well."

As the paper was winging its way to London, *Nature* senior editor Henry Gee was e-mailing an irate message to Barbara Moffet in the National Geographic Society's public affairs office. He told her he still had not received the paper and that there was no chance of having it peer reviewed in time to publish it, as planned, in September, ahead of the Society's scheduled October presentation to the media and the simultaneous publication of Sloan's article in the

November magazine. Gee copied Rowe, Currie, and Xu, but not the Czerkases.

Unknown to Rowe's colleagues and to Sloan, on August 14, the day after the paper was mailed, Rowe responded to Gee with an e-mail. He'd been "sucked into" the project, Rowe wrote heatedly; he had "no idea of just how poorly the entire enterprise" had been conducted; and "the publicity circus that the Czerkas's [sic] have tried to orchestrate with [the National Geographic Society] has been driving way too much of the project, and that I just hope that it hasn't now completely [expletive] the scientific side." Still, he said, *Archaeoraptor* is "a very important specimen" and that was why he'd "signed on to this drowning party—and why I guess I'll put in a few more hours to try to straighten out the whole mess."

Sloan reacted with surprise when I read the message to him. "If Tim had given us even a sense of his outrage at that time, it would have made all the difference," he said.

On August 20, in a "Dear Dr. [sic] Czerkas" e-mail, Gee wrote, "We would not be prepared to consider this manuscript for possible publication in *Nature.*" Gee gave no hint of the paper being inadequate or wrong, only blaming NATIONAL GEOGRAPHIC for refusing to hold off publication indefinitely to permit full peer review.

Shifting gears overnight, the scientists dashed off a subtly altered version of their paper to another journal, *Science. Science* farmed the paper out for peer review and then rejected it, saying it required more proof of *Archaeoraptor*'s birdlike qualities. Another rewrite followed. Another rejection. Another red flag.

Currie and Czerkas continued to assure Sloan and Allen—even after the millions of yellow-bordered magazines began rolling off the presses—that the paper would be published somewhere, even if only by the Blanding museum. It never happened. Thus, the GEOGRAPHIC was out on its own limb, lacking the scientific backing it so badly wanted.

A dog-and-pony show for reporters on October 15, and the article itself, churned up the expected "missing link" publicity—and set the stage for the magazine to take a pratfall. Flaws began appearing almost immediately. At a meeting of the Society of Vertebrate Paleontology in Denver, October 20-23, some scientists in the holdout group that opposes the birds-from-dinosaurs theory used the forum to disparage the article. Rumors flew. Rowe presented a paper on CT scanning of fossils and, ironically, given his previous e-mail to Gee, stated: "I found myself as an author of a paper returned to us, saying the specimen had been doctored. I take exception to that, but now we have a tool to study it."

Storrs L. Olson, curator of birds at the Smithsonian Institution and a leading opponent of the theory, came down hard on *Archaeoraptor.* One of Olson's main concerns, but by no means his only one, was over the esoteric process of naming a fossil, a privilege normally granted the author of the scientific paper describing the specimen. In this case, since the only published use of the name *Archaeoraptor liaoningensis* appeared under Chris Sloan's byline in the GEOGRAPHIC, he won the dubious distinction by default. His surname is now appended to the full scientific moniker, *Archaeoraptor liaoningensis* Sloan. This further embarrassment could have been avoided if the article had simply referred to an "unnamed fossil," Sloan told me.

But all this inside-paleontology quibbling soon deteriorated into a footnote. On December 20, Xu Xing sent e-mails to his co-authors and to Sloan, bluntly smashing the missing link. "I am really sorry to tell you a bad news!" he began inauspiciously in strained English. A contact in Liaoning had shown him the counterslab of the *Archaeoraptor* tail—joined to a dromaeosaur body. Xu could see plainly (as I could when he showed it to me a month later in his Beijing lab) that the tail impression and a pair of flanking yellow iron oxide stains were perfect mirror images of the piece glued into *Archaeoraptor.* "I am 100% sure . . . ," Xu wrote, "we have to admit that *Archaeoraptor* is a faked specimen."

"I am 100% sure," Xu wrote, "we have to admit that *Archaeoraptor* is a faked specimen."

The entire mess collapsed quickly:

NATIONAL GEOGRAPHIC published a cleaned-up version of Xu's letter in its March issue, at his request changing "faked" to "composite."

The Czerkases fell into despondency and then fought their way back, holding out hope against hope. They finally conceded defeat on April 4, when Stephen told a gathering of paleontologists in Washington that he and Sylvia had made "an idiot, bone-stupid mistake." At that meeting, organized by the National Geographic Society in an attempt to put an end to the fiasco, independent scientists for the first time examined *Archaeoraptor* and Xu's second fossil side by side. They concluded beyond all doubt that the tail belonged to the second fossil.

A shame-faced Philip Currie said getting involved in the *Archaeoraptor* saga was "the greatest mistake of my life."

Tim Rowe felt vindicated, claiming that his scans proved right from the start that the fossil was a fake.

Chris Sloan feared he did great damage to his credibility at the magazine. "I thought I was bringing in more than was expected, and it turns out I was dragging in a monster."

And Bill Allen says he's learned the wisdom of a saying scientists have long shared. "'Extraordinary claims require extraordinary proof.' We had an extraordinary claim, but very ordinary proof." □

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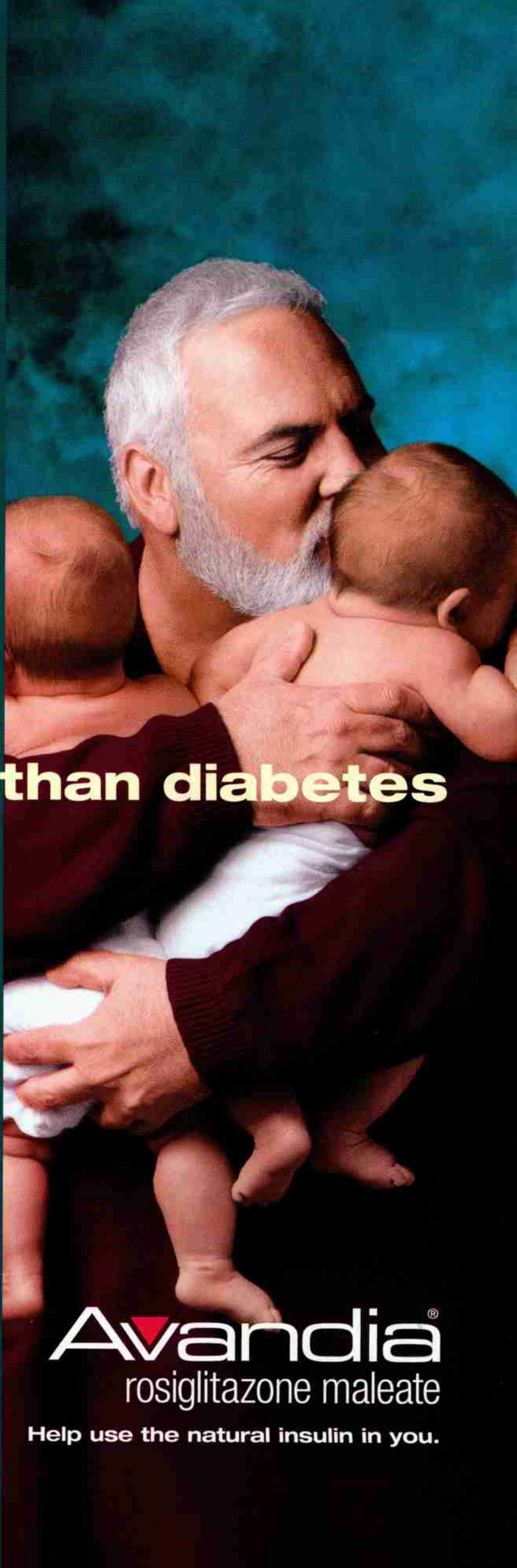
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MEGATRANSECT

Gorilla Gathering

One hundred three and counting. That's the number of lowland gorillas researchers in Congo have identified at this natural clearing called Mbeli Bai, a hot spot for the study of gorilla social life. "It's hard to see gorillas in the forest, but this place is wide open," says staff photographer Michael "Nick" Nichols, who visited Mbeli while doing reconnaissance for the Megatransect story in this issue. Gorillas are a favorite subject for Nichols, so it was hard to leave this picture out of the article. "But we knew that the next section of the Megatransect would take us through gorilla territory," says Illustrations Editor Kathy Moran, who guided the project. "We decided to gamble on covering the animals there." Did Nick find them? Stay tuned for part two of this epic adventure in spring 2001.

MORE ON OUR WEBSITE

You can send this picture as an electronic greeting card at **nationalgeographic.com/ngm/finaledit/0010**.

ON ASSI

ON THE ROAD, IN THE FIELD,

ARIZONA

Low-Tech Flight

A handmade plane flies up, up, and away, but not too high and definitely not too fast.

"Moseying along like a little moped" at 40 miles an hour above Tucson, Arizona (left), photographer Adriel Heisey keeps his plane at a safe 800-foot altitude. When he's "Sky-High Over the Sonoran," he sometimes flies less than a hundred feet above the uninhabited desert, "but so slowly it doesn't feel dangerous," he says. "We're not talking finesse here. I just have to keep from hitting things." Adriel, who lives in Tucson, hauls his 450-pound aircraft in a trailer, unloads it in about five minutes (right), and unfolds it by himself. "Once I arrive, it's less than half an hour before I'm in the air," he says. Adriel's book, *Under the Sun: A Sonoran Desert Odyssey,* will be published this month.



ADRIEL HEISEY (BOTH)

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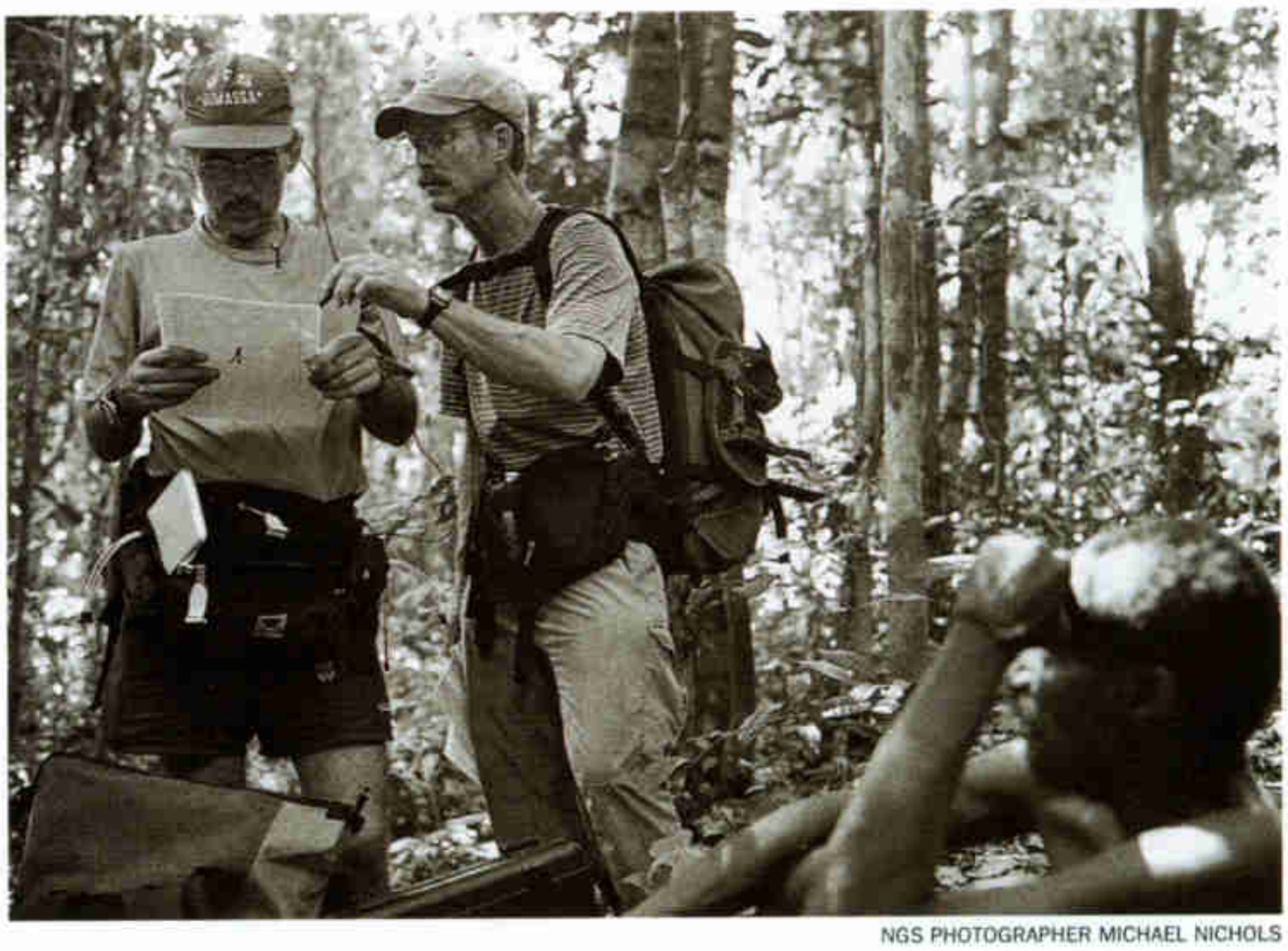
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REPUBLIC OF THE CONGO

No Day at the Beach



NGS PHOTOGRAPHER MICHAEL NICHOLS

The Megatransect trek across Africa was one of the most challenging expeditions author David Quammen has undertaken. It was also one of the most satisfying. David, at center, with Megatransect leader J. Michael Fay and a Pygmy guide, prefers "assignments that provide an excuse to get wet, dirty, sweaty, or freezing cold. This one qualifies well on the first three."

Hiking through the forests and swamps of the Congo, he faced a variety of threats such as "infected feet, nasty ants, and the occasional scared but dangerous gorilla or elephant. Have I mentioned the ants? There are several different species to watch out for, some that sting, some that bite, some that bite to hold on and then sting again and again," says David. Yet he found this "a rather pleasant forest, as swampy tropical forests go."

The experience reminded David, a novelist turned science writer who has won two National Magazine Awards, of his whitewater kayaking adventures in Chile and New Zealand. As on those occasions, he says, "I felt pushed to the limit of my strength and my skills every day, trying to keep up with people far stronger and more skilled."

WORLDWIDE

On her first ocean voyage, an 11-day cruise to report on new research in ocean geography, writer **Jennifer Ackerman** (below) made an unpleasant discovery: She was prone to seasickness. "I never got my sea legs," she admits. Still, Jennifer relished the cruise. "It's such a different perspective writing from out there." While away, she e-mailed tales of daily life on ship to her daughter Zoë's second-grade class in Charlottesville, Virginia. "They loved the idea of a bunch of scientists jumping rope on deck for exercise," she says.



NGS PHOTOGRAPHER MARK THIESSEN

Marine biologist **Rich Lutz** of Rutgers University charts the rapid renewal of life at deep-sea vents and finds new life-forms there. "We always find new species—that's one of the joys," he says. Rich has made more than 50 dives to the ocean floor. He named three "roosts"—geologic features formed by thermal vents—off the Gulf of California after his children: Rebecca, Ryan, and Richie.

Longtime contributor **Cary Wolinsky** scored a few firsts while covering ocean geography. He did his first work underwater, shot his first extensive wildlife photography, and had his first chance to work with an old Boston University classmate, photographer **David Doubilet.** "It's important to keep trying new things," says Cary. "If you do the same things over and over, you lose some of the adventure."



CHUNG KUN SHIH

A Pulitzer Prize-winning foreign correspondent with 30 years of reporting from Asia behind him, **Lewis M. Simons** (above, at left) set out to discover how scientists, and this magazine, were misled about a fake dinosaur fossil. "I was fascinated with the notion of how this fraud had been perpetrated and got through top-notch editors and scientists," he says. His investigation took him to China, where the tale began and where Charlie Magovern, at right, a Boulder, Colorado, fossil dealer, guided him through the arcane world of "rock and fossil talk."

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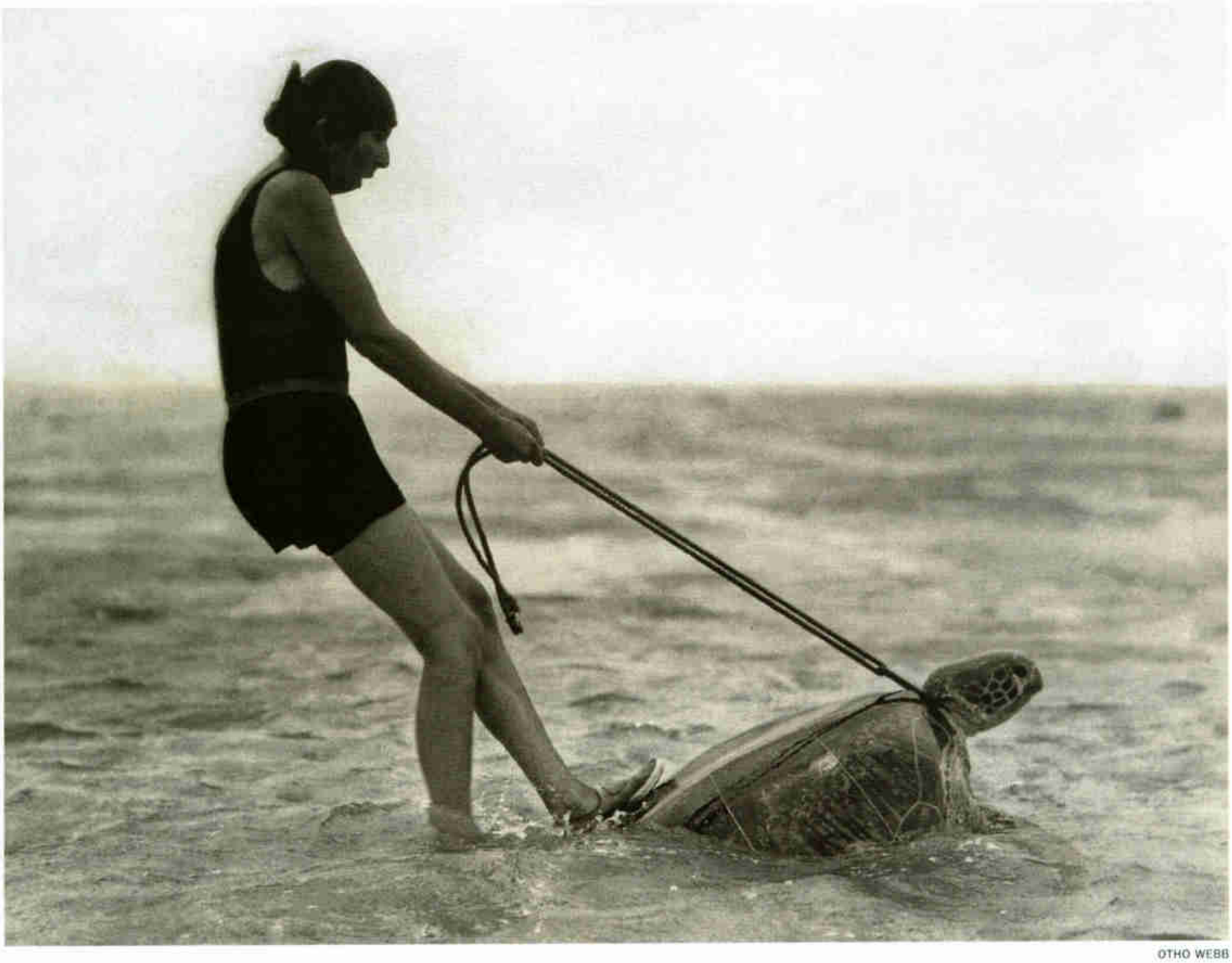
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Flashback



OTHO WEBB

OCEANS

Shell Game

On Australia's Mast Head Islet visitors engaged the local fauna in a "turtle derby" by climbing upon the shells of sleeping green turtles. "Thus surprised, they scrambled over the sand, plowing quaint furrows with their flippers. . . . Once in fairly deep water, the turtle won the game. A dive unseated the rider, who splashed ashore for another little joyride to the sea," wrote Charles Barrett in our September 1930 article "The Great Barrier Reef and Its Isles," where this photograph was first published.

The riders' reins did less damage than another local specialty, according to the article. "A turtle-soup factory, established . . . many years ago, still carries on business. During a recent season 36,000 tins of soup, representing about 1,000 turtles, were manufactured in this lonely place."

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